

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

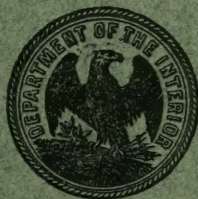
JOSEPH A. HOLMES, Director

INTERNATIONAL CONFERENCE OF
MINE-EXPERIMENT STATIONS

PITTSBURGH, PA., U. S. A.

SEPTEMBER 14-21, 1912

COMPILED BY
GEORGE S. RICE



WASHINGTON
GOVERNMENT PRINTING OFFICE

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INTERNATIONAL CONFERENCE OF MINE-EXPERIMENT STATIONS, PITTSBURGH, PA., U. S. A., SEPTEMBER 14 TO 21, 1912.

Compiled by GEORGE S. RICE.

PURPOSE OF CONFERENCE—MINUTES OF SESSIONS.

INTRODUCTION.

In 1911 the Director of the United States Bureau of Mines instructed the chief mining engineer of the bureau, during an investigation of coal-mine safety conditions in Europe, to ask the directors of the various mine-experiment stations whether they would favor a European conference. The majority of the officials in immediate charge of experiment stations favored the plan, and Victor Watteyne, inspector general of Belgium, suggested that the United States call such a conference to be held immediately after the Eighth International Congress of Applied Chemistry, which was to assemble in New York on September 3, 1912.

Accordingly, invitations were issued by the United States Government to those countries having mine-experiment stations, namely, Austria-Hungary, Belgium, France, Germany, and Great Britain, and to those that contemplated the establishment of such stations, Canada and Mexico. All but Great Britain and Canada accepted; Mexico designated a representative, who later found it impossible to come. The Government of Great Britain in declining, expressed regret at its inability to accept; an informal statement was made that the opening of the experimental gallery at Eskmeals, England, occupied the attention of the officials in charge.

Delegates were appointed by their respective Governments as follows:

Austria-Hungary, Julian Czaplinski, royal mining engineer.

Belgium, Victor Watteyne, inspector general of mines.

France, J. Taffanel, director of the Lievin experiment station.

Germany, Carl Beyling, bergassessor, director of Dortmund experiment station.

United States, Charles E. Munroe, consulting explosives expert and George S. Rice, chief mining engineer of the Bureau of Mines.

Subsequently Mr. William O'Connor, a mining engineer and mine operator of Wales, who opportunely appeared at the Pittsburgh sta-

tion with letters of introduction from the South Wales Institute of Engineers and from prominent mining officials of Great Britain, was unanimously invited to take part in the meeting as an unofficial representative of Great Britain.

Messrs. Beyling, Taffanel, and Watteyne were met in New York on September 3, by George S. Rice, who accompanied them to Washington, where they were welcomed by Director J. A. Holmes, of the Bureau of Mines, and where, with the delegates to the Eighth International Congress of Applied Chemistry, they were presented to President Taft.

Mr. Taffanel was unfortunately called back to France just before the scheduled time of the conference on account of a mine disaster; the other delegates, including Mr. Czaplinski, convened at Pittsburgh on the morning of September 14. Mr. Rice, representing the Director of the Bureau of Mines, acted as temporary chairman, and called the meeting to order.

CHAIRMAN'S OPENING ADDRESS.

The chairman opened the conference with the following remarks:

GENTLEMEN: The director of the United States Bureau of Mines was to have opened this conference. Unfortunately, circumstances delay his arrival, so he has asked me to represent him in this pleasing duty. I therefore, on his behalf and on behalf of the Government, bid you a cordial welcome to this country and to this conference.

It is a source of pleasure to the representatives of this Government that, in spite of the late date at which the invitations were issued through the Department of State, of the six great nations that now have coal-mine testing stations, five, including the United States, have appointed official delegates. The Government of Great Britain replied that it regretted that there was not sufficient time to permit making arrangements to send a delegate, and that the members of the commission are now conducting important experiments at the Government station and are so occupied with that work that they are unable to attend.

It is with great regret that I have to announce that the eminent investigator, M. Taffanel, one of the two official delegates to this conference from France, who has been attending the International Congress of Applied Chemistry, was recalled a few days ago on account of a serious explosion at the Clarence mine, in the Pas de Calais district, France. His absence is a serious loss to this conference, and I am sure that I am stating the views of the various members in expressing sympathy for M. Taffanel in the misfortune of this mining disaster. It will undoubtedly interest the conference to report what M. Taffanel told me recently in Washington that the Clarence mine is very gaseous and subject to spontaneous fires—a most serious combination, as all mining men know. I have personally observed the excellent preventive means against dust explosions taken in the French mines as a result of M. Taffanel's investigations at the Liévin station. M. Weiss, the other delegate from France, has not yet arrived, I believe, but we hope that he will be with us at the subsequent sessions.

The plan of a cooperative arrangement between the representatives of the different testing stations was discussed by the mine-accident committee of this bureau, and last summer when I was sent to Europe with a party of engineers to visit European coal mines and testing stations, the director suggested that I make inquiry informally of the directors of the several stations as to whether they would approve of the plan of holding a conference. All those whom I saw expressed themselves as being pleased

with the idea. M. Watteyne, the delegate from Belgium, suggested that in view of the international congress of applied chemistry meeting in America this summer it would be an excellent idea for the United States to invite the various countries to send representatives who might attend this congress, and then have a special conference on the mine-testing work. On my return the director expressed pleasure at the suggestion, and invitations would then have been issued had there not been uncertainty about the action of Congress regarding appropriations for the year's work of the bureau. Owing to delay in making these appropriations the invitations could not be sent earlier than they were.

Besides the official delegates who are present, we are fortunate in having with us a number of visitors from abroad as well as from this country.

As a result of a preliminary conference with the official delegates, I am pleased to announce that the visitors present may attend all those meetings, tests, and demonstrations indicated on the program, except the business meeting on Thursday evening and possibly certain other business sessions.

I now take pleasure in introducing Mr. Herbert M. Wilson, engineer in charge of the Pittsburgh testing station, who will give you a few words of greeting from the local staff of the bureau.

ADDRESS BY H. M. WILSON.

Mr. Wilson spoke as follows:

MR. CHAIRMAN AND GENTLEMEN: The engineers of the United States Bureau of Mines, with headquarters in Pittsburgh, greet you and are delighted to have you with them. Not only we, but the people of Pittsburgh, and especially the mining people centered in Pittsburgh, feel greatly honored that an official international conference having to do with such important subjects as you are to consider should meet in their city. Pittsburgh is very properly chosen for the convening of the first international conference to consider matters that may improve the conditions of safety and of efficiency in the mining of coal, because it is one of the greatest coal-mining centers in the world, representing a production of 200,000,000 tons annually, and with a mining pay roll of over 300,000 men.

The program of the conference is before you, and I am sure that this country, as well as your own countries, look forward with great expectations and hope of the good that will ultimately come of the proceedings of this body.

ADDRESS BY CHARLES E. MUNROE.

The temporary chairman then introduced Prof. Charles E. Munroe with these words:

I take pleasure in introducing Prof. Charles E. Munroe, of Washington, D. C., who is consulting explosives chemist of the bureau, and whose name is well known to many of you, who will extend some words of greeting on behalf of the Washington contingent of the bureau, and also for the explosives chemists.

Prof. Munroe spoke as follows:

I am very glad to add my voice to the expressions that have been made to you. I had no intimation that I was to bear a part in this manner, but what has been said has been said so admirably that it leaves me little to say. I may perhaps call attention to the fact that our country has been a little laggard in these investigations, and that you gentlemen in Germany, France, Belgium, and England were years in advance of us in investigating the problems of explosions in mines and the methods by which they might be reduced in number and might be mitigated or suppressed.

Our peculiar governmental organization prevented our sooner undertaking the solution of these problems, though they were before the minds of many and had been brought forward publicly to attention. This peculiar governmental organization requires a special kind of individual to solve its Gordian knots, and it was not until the present director of the Bureau of Mines appeared, who has a gift for cutting knots and expressing a purpose, that we were able to do what we have done. I think that in the time this bureau has been organized a reasonable amount of work has been accomplished—all I think that might have been expected of it in this time.

I am speaking in this way because my attention has been limited; I am a viewer rather than an actor; I have seen what others are doing; I have noticed what they have initiated. I remember that at the outset of the organization of this station we had the benefit of your advice, your comment, and your criticism, and of your long experience, all of which have proved so valuable to us in the work we have done.^a

We have now gained some little experience, in that we have seen some of the problems that are to be solved; also we have seen many great difficulties that must be overcome.

ADDRESS BY MR. WATTEYNE.

Mr. Victor Watteyne, of Belgium, was introduced by the chairman and made the following remarks:

First, I congratulate the Bureau of Mines for the great work it has done so rapidly. Only four years ago you were just beginning; now you have done a great many things. I congratulate Dr. Holmes, who is the promoter of all this, and I congratulate also the Bureau of Mines, which has practically initiated the idea of uniting the work of the testing stations.

The questions under investigation are not new. The testing station at Frameries was established many years ago; and at Berlin nine years ago it was suggested by an English delegate to conduct the testing station at Frameries as an international testing station, and to appoint a committee that would decide what experiments should be made. Belgium was not the first to have a testing station; Germany and Austria already had testing stations. Belgium, being a neutral country, was considered eligible, and had been suggested as the place for an international testing station, but the idea was not practicable. It was impossible to have an international committee coming from all parts of the world working at Frameries and indicating the program of the experiments to be made. However, the idea was presented again at the congress at Liège in 1905, but it was rejected also.

Now, Dr. Holmes proposes that the five or six testing stations in the world unite their work. The question of unification has already been spoken of in a preliminary meeting, and we quite agree. We, meaning Dr. Holmes, Mr. Beyling, Mr. Taffanel, and myself, had a meeting in New York before coming here, as Mr. Taffanel had to return to France. We considered the leading idea that ought to prevail in our conference. This must not be a question of indicating to each testing station, generally speaking, the way in which it must work, for such a course would prevent the development of initiative at the different testing stations. The initiative and the desire to do better than another must be preserved because they make for the good of humanity, for the good of the problem with which we are dealing hand in hand. Some of the results obtained at the different testing stations—Pittsburgh, Gelsenkirchen, Frameries, Liévin, and Altofts—are rather contradictory. There must be a reason for that, and seeking the reason will be one of the purposes of the international studies. Of course, if the same question is solved differently in different countries the solution is cer-

^a See Technical Paper 21, Bureau of Mines: The prevention of mine explosions, by Victor Watteyne, Carl Meissner, and Arthur Desborough.

tainly not exact in several points; if we get different results it is a proof certainly that we at first made mistakes—perhaps all of us. It is very important to make no important error. For example, it would be a deadly mistake if we accept an explosive as safe when it is not; we might cause the death of some workmen by such a mistake.

It is very important to study such questions with care. At this moment I can not enter into details of what might be done, but you understand it is one of the points we have to consider together, one of the points that would make the conference of great and positive utility. Another point—we may have some experiments that we will study together, but such as are not susceptible of being tried in all the testing stations. For instance, in Frameries, if we wish to have a large explosion like one tried in the gallery of another country and know what has occurred in that explosion and what are the means of preventing its propagation, I could not experiment with exactly the same conditions because my testing station is not made or arranged for that; but I could have a test of a similar kind. Such a matter is, therefore, one of our problems to be considered at this conference. This conference should, therefore, prove of great value to all nations. I congratulate again the Bureau of Mines, and we all feel very grateful for the opportunities presented through its invitation.

REMARKS BY MR. BEYLING.

Mr. Beyling, of Dortmund, Germany, was introduced. He asked to be permitted to speak in German. His remarks as translated were as follows:

We appreciate very much the calling together of the international conference for the purpose of trying to settle some mining problems, and, as Mr. Watteyne has stated, there are very difficult problems, and we can do only our best. We have nothing to add to what Mr. Watteyne has stated and his general suggestions as to the conduct of the conference.

ADDRESS BY DR. CZAPLINSKI.

Dr. Czaplinski, of Austria-Hungary was then introduced, and also addressed the conference in German. A translation of his address follows:

The Austrian Government accepted very gladly the invitation to attend this conference, because of the disagreement that has arisen heretofore between the various mining testing stations, and it is high time that we come together and try to unify our methods.

In Austria we deal mainly with three problems. The first problem is that of mine gases, the handling of which we solved in Austria during 1890 to 1898; we have advanced so far in devising and applying safety measures that we have had no accidents of any importance from this cause during the past 15 years in Austria, although some of the coal mines of Austria give off the greatest volumes of methane of all the mines in the world.

The second problem is that of explosives. Without explosives, of course, little work can be done in mines. The problem is, therefore, to procure explosives that, within certain limits, are safe to ignite in the presence of gas or coal dust. This problem we have not as yet solved.^a We have two testing stations now and a third is now being

^a In Austria, blasting with dynamite is prohibited in mining coal. For this work safety explosives have to be used, one of which is mainly an ammonia-salt-peter compound (Gasdynammon), the other an ammonia-gelatin compound (Pannonit).

erected in Bohemia; these will act together in investigating the question of safe explosives.

The third problem is that of coal dust. Because of the disaster at Courrières this problem has been called to our attention more forcibly.

In my district near Segen-Gottes, in the mines of the Russitz Mining Co., I have erected a large station for the experiments on coal dust; I have also published a report that is probably familiar to you. We have found means of preventing coal-dust explosions, and have been working along the same lines as the experimental station at Liévin. I am corresponding with Mr. Taffanel and exchanging my publications with him, and I am very sorry he is not present. Lately Mr. Beyling's experiments on coal dust simulated my own. I have also investigated the results in England, which differ greatly from ours.

I welcome, therefore, the international conference because its object will be to reach an agreement. In Austria we have three stations, and we have established a basis so they will be able to work together along parallel lines. I will take pleasure later in describing the basis for the work of the three stations.

ADDRESS BY WILLIAM O'CONNOR.

The chairman then introduced Mr. William O'Connor, of South Wales, who had been invited to attend the meetings as an unofficial delegate. Mr. O'Connor spoke as follows:

I am scarcely prepared to take part in the discussion. I might say that in England experiments have been carried on by our mine officials at Altofts under the direction of Mr. W. E. Garforth, and the results have been considered so important that after a little agitation the Government has taken up the question of erecting a special testing station. One of the difficulties in experimenting on the scale on which the experiments were carried on at Altofts was that for some miles around the explosion broke all the windows, frightened a great many people, and had a very unpleasant effect on those in the vicinity, and I think it was particularly on that account that the new location was decided upon.

The new station will be erected in close proximity to Messrs. Vickers' testing works. Any explosion effects will be little noticed because of the large number of explosion tests which are carried on by Vickers without difficulty, owing to the isolation of the site. There are no habitations within a considerable distance, so that no one will be affected by them. I do not think that any experiments have been conducted on the new site, but I think the gallery will be about 800 feet long and about 7½ feet in diameter. I have not the exact dimensions with me, and must give them from memory. In addition there will be smaller galleries. In the main gallery it is hoped to carry experiments a step farther than at Altofts. I may say that the results attained at Altofts have convinced all of the serious dangers from coal dust.

One of our most serious dangers in regard to coal dust is that of ignition, and we consider as our two principal sources of ignition the igniting of small quantities of fire damp and the use of explosives. We have a number of instances in which ignition took place in mines long abandoned, but as there was no loss of life we dismissed this phase of the matter as not very important. In regard to the ignition of small quantities of fire damp in such a way as to create explosions, a new act came in force in July which lays down very stringent regulations as to the percentage of gas that may be allowed in mine air. In some mines the use of explosives is prohibited altogether. About half of the coal produced is now brought down without a single shot. In regard to palliative measures relative to coal dust, under the new act there is a special officer appointed to see that such measures are taken. We hope that they will have some good effect on the death rate caused by coal-dust explosions.

FORMAL OPENING OF FIRST MEETING.

At the conclusion of the remarks of Mr. O'Connor, the temporary chairman stated that it was understood at the preliminary conference that the chairman of each meeting should be one of the foreign delegates, and that each would serve in turn in the alphabetical order of their respective countries, but that for the first day's meeting it had been informally suggested by some of the foreign delegates that, as they were not quite familiar with the situation, it might be best to call upon Prof. Munroe to preside as the chairman. This suggestion was formally adopted by the conference, and Prof. Munroe took the chair. He expressed his pleasure at the honor of presiding and then stated that it appeared advisable to elect a secretary who should remain in office throughout the conference and keep the records of the meetings. The conference thereupon elected Mr. Rice as secretary.

The chairman (Prof. Munroe) announced that a series of papers prepared by members of the staff of the Bureau of Mines, presenting various matters for the consideration of the conference would, with the consent of the delegates, be read. Accordingly, he called upon Mr. Rice to present his paper "on The Methods Employed by the Bureau of Mines in Investigating Coal Dust or Gas."

After the paper had been read, the meeting adjourned to witness a coal-dust explosion test at the experimental mine near Bruceton. The explosion or inflammation, the details of which (No.17) are given on pages 44 and 45, was small, the flame traveling outward only 100 feet and inward 50 feet.

The smallness of the explosion was a surprise, as two days previously, in an experiment with similar loading and other arrangements, the explosion had been strong, flame extending 175 feet outside the opening, as described on page 44. The only apparent difference in the conditions of the two tests was that the relative humidity of the outside air was 46 per cent on September 12, the day of test 16, whereas it was 78 per cent (following a rain) on September 14. This difference may have caused the walls of the mine entry to be wetter on the latter date.

MINUTES OF MEETING OF MONDAY, SEPTEMBER 16.

On Monday, September 16, 1912, the meeting of the conference was called to order at 9.30 a. m., by Mr. Victor Watteyne, of Belgium. The minutes of the meeting follow:

MR. WATTEYNE. I think that by reason of the efforts of the Bureau of Mines the mining-fatality rate in a few years will be very much lowered. It seems to me that in the papers presented at the last meeting we had the causes of the many explosions in coal mines clearly indicated. It must be added that the operators in the coal mines

of America are obliged by the stress of circumstances to produce very much and very rapidly, because they are obliged to produce very cheaply, and this is indirectly the cause of the bad conditions, but I think there is nothing that we can do to prevent this. We must take that into account and direct the struggle, not against the conditions of the coal business, but against the consequences that result, for example, from the vast and seemingly unavoidable use of explosives in this country. What must be done is to have the explosives used with greater safety. We can not make them entirely safe, but we can make their use much safer if they are of good quality, that is, the permissible explosives that the Bureau of Mines has tested and has already introduced extensively in the coal mines of America. The precautions that are to be taken in using these explosives are being considered by the Bureau of Mines, and I know that the special engineers of the bureau are making the operators acquainted with the best ways of using explosives. I think it is one of the best things you can do for the prevention of mine explosions.

As to the question of "shooting off the solid," I formerly deemed that the importance attributed to it in America was somewhat exaggerated, and I was afraid that the operators might be induced to consider as dangerous the blown-out shots only, and to take little care of the others. Since, we have made at Frameries many experiments, which prove that the blown-out shots are indisputably much more dangerous than the others. But I repeat that all kinds of shots must be reported dangerous, and precautions ought to be taken against them, especially by using exclusively safety explosives, the "*bourrage extérieur*" ("outside stemming"), and the like.

Another problem that has been dealt with in the previous papers is that of humidifying the mine. I say for my colleagues of Europe that this problem presents itself more acutely in America than in Europe. Generally speaking, it is much more easy and much more profitable in America than in Europe to spray or dampen the ventilating air current, because the mines, as Mr. Rice states, are shallow, the roof strata are generally good, and the conditions are favorable for humidifying the air. It is evidently a good precaution against the dangers of coal dust, which are very great here. In European coal mines, especially in Belgium, the seams are very thin and many of the operations are in rock. This difference may explain why American mines have a tendency to have more coal dust than European mines.

Consideration was next given to the instruments used in coal-dust experiment galleries, the meeting adjourning to Dr. Clement's laboratory.

Dr. CLEMENT. We have been experimenting with the manometer for recording the pressure of coal-dust explosions in the mine. Dr. W. O. Snelling, formerly connected with the bureau, suggested that we could get rid of the inertia of an ordinary gas-engine indicator by using some kind of material whose electrical resistance would change with the pressure. So we have tried a great many different materials—metals, carbonized cloth, and carbon disks of various kinds—and we finally decided on a carbon disk. You, of course, know that if you apply pressure to a pile of carbon disks the electrical resistance changes. Now, if you can find out and define the relation between resistance and pressure, then if you measure the variations of the resistance, in that way you can determine the pressures. We have not perfected this machine yet; we are still making some experiments with the oscillograph to measure the pressures.

Demonstrations and explanations of the apparatus (described in Dr. Clement's paper, p. 41) were then given in the physics laboratory of the experiment station.

At this point the chairman read a letter from the Secretary of State for the Home Office of Great Britain, stating that Sir Edward Grey regretted that His Majesty's Government found it impossible to be represented at the conference.

The conference next adjourned to the gas laboratory, where Mr. Burrell demonstrated and explained methods and apparatus for gas analysis.

The conference returned to the library, where a demonstration was made of a new instrument designed by members of the bureau for the purpose of taking automatically three gas samples in rapid succession.

Dr. Clement then described a number of curves showing the results obtained with laboratory apparatus for testing the inflammability of coal dust.

The conference adjourned for lunch, later going to the experimental mine, near Bruceton, to witness a second coal-dust experiment (No. 18, described on p. 45). In this test ignition was made at the face of the right-hand stub to determine whether an explosion would go inby the main entry, as well as outby. The explosion did go inby, although the explosion was not violent.

EXCURSION OF SEPTEMBER 17.

On Tuesday, September 17, 1912, the members of the conference took part in a Monongahela River excursion with the delegates to the International Congress of Applied Chemistry, visiting the Clairton plant of the Carnegie Steel Works, and in the evening attended an entertainment given in honor of the congress.

MINUTES OF MEETING OF WEDNESDAY, SEPTEMBER 18.

The meeting of Wednesday, September 18, was called to order by Mr. Carl Beyling, of Germany. The chairman presented for discussion the subject of explosives.

Dr. CZAPLINSKI. The results in Austria in the testing of explosives have varied, owing to lack of uniformity in methods, and for this reason we have arrived at a common basis for investigations at all of our stations. Explosives have been investigated most extensively by the army department. My investigations have been in the development of so-called "safety explosives," as they are the only ones allowed in our mines. Such explosives are safe only up to a certain point, and the main object in testing them is to determine the proper safety limit. We test our explosives under the most dangerous conditions; that is, under such conditions as are most favorable to ignition of gas and coal dust.

Second, we test our explosives under exactly the same conditions, so as to have a uniform basis and thus enable us to compare the safety of the various explosives.

Our method differs entirely from the method used in England, France, or Belgium. In England, for instance, a small charge is used in a cannon with tamping; in France the ignition temperature is determined; in Belgium the charge is fired in a cannon

without tamping; in Austria we fire the explosive without stemming, the effect being that of a suspended shot, because in this way we get identical conditions for all our tests. The explosives rest freely on steel plates and stand vertically. On the steel plate we place two lead cylinders or blocks on which the explosive is placed in a parchment wrapper. The diameter of each explosive is 40 mm. The explosive is fired by an electric detonator. In the test the charge starts with 50 grams, being increased by 50 grams in each successive test up to the limit. The cap is either 1 or 2 grams, according to the explosive. The lead blocks show whether the entire explosive detonates. The tests are the same for all explosives. We formerly used a cannon, but as the size of the bore hole changes after each shot, we did not have the same conditions in all tests. Neither does a cannon simulate the real conditions in a mine. In a mine the shot is made in the coal, and it has to perform some work, whereas in a cannon it does not perform any work. In the explosion chamber we use either gas or coal dust, or both. Through these shots we determine the safety limits of the explosives.

We also test each explosive in bomb cylinders (Bichel gages) according to the method adopted in Berlin. Each explosive must show certain results; otherwise it can not be used in a mine.

Third, this method of testing on the lead blocks shows whether there is complete detonation. Those explosives showing incomplete detonation, by leaving a residue, are excluded from further tests because they are dangerous.

We also measure the detonation temperature. An explosive that gives a temperature of over 1,500° C. is excluded.

A hole is made in the ground and a cylinder made of sheet iron is placed in it. The cylinder rests on two lead blocks, and the latter rest on a steel plate. The whole thing is surrounded by clay. We put 200 grams of the explosive in the hollow sheet-iron cylinder; a cap is placed on the top. We discharge the shot and photograph the flame. The flame must be short and dark. If the flame is too long the explosive is excluded.

After the explosive has stood all of these tests, it is tested on a small scale in the mine under strict supervision, and the gases resulting from an explosion are analyzed. If the explosive stands the small-scale test, then it is applied on a large scale, and the combustion gases are analyzed, and if it succeeds on a large scale it is declared a safe explosive. It must not produce any monoxide. The manufacturer is obliged to make his explosives exactly the same as the one tested. If he furnishes more than one kind of explosive each kind is tested in exactly the same manner.

Mr. BEYLING. The main difference between the tests in Austria and those in other countries is that in Austria the charge stands upright, and in other countries it is shot in a cannon. I myself do not think that the Austrian method is the proper one. First of all, the conditions for ignition are not as favorable as when the charge is confined. In the second place, with an unconfined charge it is impossible to ignite coal dust. I do not think that the test of coal dust can be carried out with a free charge standing upright and unconfined. Third, I consider the conditions in a cannon as more in correspondence with the conditions in our coal mines.

Mr. Czaplinski has stated that in a cannon the explosive does not perform any work; we know that the most dangerous shots are exactly those that do not perform any work in the coal, that is, the blown-out shots, exactly like those in the cannon.

The objection of Mr. Czaplinski as to increase in size of the bore hole I do not think so important. Of course, if it has changed its shape entirely it must be used no longer. There is another point in favor of shooting from a cannon. We do not know yet what causes the explosion, whether it is the flame, or the after damp, or the duration of the detonation, but I do not doubt that the composition of the detonation gases has considerable influence on the result—whether the explosive will cause an explosion or not. Naturally these detonation gases will differ according as to whether the charge detonates when it is free or when in a cannon. It is probable that we will

obtain the same gases if fired from a cannon as when fired in bore holes in a mine. I would consider it desirable to reach some uniform method of testing explosives.

MR. WATTEYNE. In Frameries the methods of mining, the charge of explosives, and the relative safety of explosives are almost identically the same as in Germany, and the reasons put forth by Mr. Beyling in order to justify his methods are the ones that guided us in Frameries. I thoroughly agree with the views expressed by Mr. Beyling. The importance of blown-out shots is very great; the difference in the safety of explosives when doing work and when they do not do any work is exceedingly great. It is an additional reason for preserving the method of using a rigid cannon, in which no work is done by the explosive. The cannon gives rather severe conditions.

On studying at Frameries the "bourrage extérieur," that is, an accumulation of stone dust at the mouth of the shot hole, we have been led to make some experiments under quite the same conditions as are found in coal mines and, for that purpose we have begun an underground gallery in a forest (Bois de Colfontaine) not far from Frameries. That forest is over the coal measures, so that in tunneling we have the same rocks as encountered in coal mining. The gallery is a rock drift. It is to be noted that, unlike in America, Austria, and often in Germany, where they shoot principally in coal, in Belgium the underground galleries are frequently in rock. Shooting in coal is not permitted.

At this point the discussion was adjourned for lunch. Following lunch the members of the conference again visited the experimental mine at Bruceton to see the third experiment (test 19; see p. 45). The igniting charge in a cannon was at the face of the main entry. Only a limited inflammation occurred, owing probably to the damp condition of the mine. The relative humidity of the mine air was 95 to 97 per cent, there were pools of water standing in a side ditch along the entry, and the walls were damp.

MINUTES OF MEETING OF THURSDAY, SEPTEMBER 19.

At the meeting of Thursday, September 19, Dr. Julian Czaplinski, of Austria-Hungary, was in the chair and announced a continuance of the discussion on explosives, which is recorded below.

MR. CLARENCE HALL. Before reading my paper I want to say a few words relative to testing explosives in a cannon and relative to suspended shots. It is my opinion that shots fired from a cannon more nearly approach the natural conditions than when tests are made with the explosive suspended. When testing explosives in a cannon we experience no difficulty in getting proper results provided we adjust the cannon after it has been used a certain number of shots. When the drill hole reaches 3 inches in diameter we put in asbestos rope or fire clay and bring the charge forward. We find that the length of the bore hole is not a factor in determining the safety of explosives. In other words, if the bore hole of the cannon is 21 inches long or 17 inches long it does not make any difference in the results. When the shots are fired without stemming, the rate of detonation is apt to be less than when confined.

Mr. Hall then presented his paper (see pp. 81-92). He also showed a number of charts giving results of tests of certain unnamed foreign explosives, the composition being given.

MR. WATTEYNE. The reason we have selected coal dust with about 22 to 25 per cent volatile matter for our standard in testing explosives is that the mines that contain such coal dust are the most dangerous, being the most dusty in Belgium. The dust

made from coal with higher percentages of volatile matter is indeed more inflammable but, generally speaking, the mines where such coals are mined are, in Belgium, much less dusty and, therefore, the danger of coal-dust explosions is not very great.

Mr. O'CONNOR. We have found that where the volatile matter is lower, the coal dust is more explosive than with high volatile matter.

Dr. BEYLING. The same conditions have been found in Germany. Although, in general, coal dust must be more dangerous the more gas it contains, our so-called "gas coal," which contains 50 per cent of gas, is hard, and does not yield much dust; moreover, the gas of the gas coals requires a higher temperature for liberation than the gas of a "fat" coal. The "fat" coal has only 20 to 30 per cent of gas, but the gas escapes at a lower temperature, and at 100° to 200° C. we can get much of this gas out. For this reason coal-dust explosions have taken place in the mines producing such lower volatile coals.

Dr. CZAPLINSKI. We find the same conditions in Austria. The explosions depend upon the gas content, and have more often occurred in the same kind of coal, containing 26 per cent of volatile matter. In the case of fresh coal there is more liability of explosions than when the coal has been exposed several days, as it then loses a great deal of its volatile content. We also found that ammonium nitrate explosives must be used when in a fresh condition, as they readily absorb water, and either detonate partly or not at all. We always have to protect them against moisture. We also found that the density of the explosive is of great importance. The ammonium nitrates used must have a specific gravity of 0.8 to 0.9. If used with density of 1 there is no detonation. By changing the density we change the explosibility. I recognize the importance of making experiments with the cannon, and will try to make another series of experiments with the cannon. I have not, however, been convinced by the objections brought against the methods of using free shots. I have always found that free shots cause coal dust to explode.

Mr. HALL. It is proposed that the United States Bureau of Mines shall have a new requirement limiting the age of an explosive, as it becomes insensitive after, say, 4 months, when it should be taken off the "permissible list." I would like to ask the views of the conference on this matter.

Dr. CZAPLINSKI. We have experienced no such difficulties in Austria for the reason that we do not have to transport explosives such long distances from the factory to the mines as you have to in the United States.

Mr. O'CONNOR. Whenever we have the least cause to suspect anything not up to the standard in any explosives in Great Britain, we prohibit their use altogether and send them back to the manufacturer. We find a great deal of difference in the time an explosive will remain unaltered in strength, according to the time of year.

Dr. BEYLING. The question raised by Mr. Hall relates to the desirability of establishing a test for explosives so as to find out after a certain length of time whether they will still detonate. Then if they do not come up to this requirement they are to be taken off the permissible list. We have no such requirement. It is very difficult to arrive at conclusions in this respect. The first consideration is the conditions under which the explosives change, and when they do not detonate properly. In Germany the explosive must be stored in such a way that it will not absorb moisture. The factories are in the neighborhood of the mines, and require less transportation than in this country.

Dr. CZAPLINSKI. I agree with Dr. Beyling in every respect. The same conditions prevail in Austria as in Germany. We have very strict regulations as to the packing of explosives. Explosives that absorb moisture must be packed four times, and the packing soaked in liquid paraffin or wax, and if stored underground they must be stored in a dry magazine.

Mr. HALL. May I ask the views of the conference regarding restrictions in the production of carbon monoxide from explosives?

Dr. CZAPLINSKI. The restriction in our country is that the explosive on detonation must not produce any carbon monoxide gas; otherwise it is rejected.

Mr. RICE. Is the determination of CO made from samples gathered from the detonation of the explosive in a Bichel gage, or from samples gathered in the mine after a shot has been fired?

Dr. CZAPLINSKI. In a mine.

Dr. BEYLING. There are no restrictions as to the production of monoxide in Germany. The miners must not go back to their places for at least 10 minutes after a shot has been fired. We have tried to determine the CO in the afterdamp. We have never found large quantities, although we know that we produce large quantities at times. It becomes so quickly mixed with the air that we can not determine the amount.

Mr. MATTEYNE. In Belgium there is no special regulation about the gas or products of explosives. We have had no special inconvenience along this line. Our mines are well ventilated, especially at the points where explosives are used, though we have more narrow places on account of the thin seams than in other countries.

Mr. O'CONNOR. We have found carbon monoxide produced by the use of carbonite. It has a cumulative effect on men and therefore the use of carbonite is to some extent restricted. We have no regulations regarding production of gases from explosives, but we do not use carbonite in places where there is any danger of affecting the health of men.

Mr. RICE. The production of deleterious gases is a matter of great importance in America on account of the almost universal use of the room-and-pillar method of mining. Very often the ventilation up to the face of a room or heading is not perfect. The faces of rooms or entries may be 100 feet beyond where the air current is moving, and the miners tend to go back too quickly to the face.

Dr. CZAPLINSKI. The conditions in Austria are the same as Beyling has described in Germany. Several shots are fired at the same time. The men do not return for 5 or 10 minutes. We have never had any trouble from poisonous gases. The ventilation is good in the working places.

Dr. BEYLING. If you fire a shot in the coal you may get carbon monoxide which does not arise from the explosive, but from the great heat to which the coal is exposed. Twenty years ago before we had any safety explosives we used dynamite in the coal. This explosive does not give off any carbon monoxide, still we had many cases of CO poisoning, which always came from the partial combustion of the coal.

Mr. HALL. We have found that carbon monoxide is produced from the coal, when a shot is in coal, owing to the heat of the explosive.

Mr. O'CONNOR. I would like to propose that the detonators used in all countries should be standardized, and that a number should be placed on each indicating the strength. We always investigate the caps, placing them on lead plates 4 to 6 inches square for testing.

Dr. CZAPLINSKI. Our blasting caps are all numbered. The numbering is based on the rapidity of breaking through lead testing plates of different thicknesses.

Dr. BEYLING. I am in favor of having a standard adopted in all countries. Have you any standard to propose?

Mr. O'CONNOR. I would propose that the detonators in all countries be numbered and that the numbers in each country represent an equal strength of detonator.

Dr. CZAPLINSKI. How shall the strength be determined?

Mr. O'CONNOR. It would be necessary to test them on one standard. I take it that a detonator that perforates a certain thickness of plate should have the same number in all countries. The standard to be in millimeters.

Dr. BEYLING. In Germany we number the caps from 1 to 10, representing definite efficiency.

Mr. Hall then explained the system in use in the United States, speaking as follows:

The bureau is now conducting an investigation to determine the relative strength of detonators and electric detonators of different compositions. The direct method of determination comprises tests to ascertain the mechanical effect of the detonators; the indirect method comprises tests to ascertain the mechanical effect of commercial explosives with which the detonators are used. The direct method, which includes the tests on lead and iron plates and on small lead blocks, and other similar tests, offers the advantage of simplicity, but it is not believed that the results of these tests show the relative efficiency of detonators. A new test, known as the nail test, which was recently devised at the Pittsburgh experiment station, has been found to give satisfactory results in determining the relative strength of detonators. This test depends on the angle formed by a nail when a detonator is fired in close proximity to it. The results of the nail test approximate more closely those obtained by the indirect test than do any of the methods previously used for the direct determination of the relative strength of detonators.

The indirect method for determining the mechanical effects of explosives, that is, the energy developed by the explosives, approximates practical conditions, and, it is believed, offers an accurate means for determining the relative efficiency of detonators. The results of tests show that when high explosives that are not too sensitive are used, the energy developed increases with the grade of the detonator. For example, the average efficiency of four different explosives was increased 10.4 per cent when a No. 6 detonator was used instead of a No. 4. Furthermore, the average percentage of failures of explosives to detonate was increased more than 20 per cent by using lower grades of detonators instead of No. 6. It is noteworthy, however, that when sensitive explosives, such as the higher grades of nitroglycerin dynamites, were tested under conditions ideal for detonation, the same energy was developed irrespective of the detonator used.

PERMANENT ORGANIZATION.

At this point the chairman announced that the technical discussion would be interrupted to allow consideration of plans for a permanent organization.

Mr. WATTEYNE. At an informal meeting in New York, with Director Holmes and Messrs. Taffanel and Beyling, we agreed on certain features that should be adopted in a permanent organization. I believe that the proposition should be made by the representatives of the United States, through the proper diplomatic channels.

Mr. RICE. It is suggested that the organization be made permanent; that meetings be held at certain intervals; that between the time of meetings communication be maintained between the representatives of the different testing stations in order to obtain prompt information as to the nature and results of tests that are being carried on; that so far as possible there shall be a uniformity or standardization of tests. I do not mean that all shall be alike, but that some method of standardization be agreed upon; that we shall interchange samples of explosives, coal dust, and other material that enter into the tests, so that we can try them in different kinds of apparatus, and thus be able to compare the results obtained at the different stations. It would be desirable that we select as chairman a representative from the country in which the next meeting will be held, and that the secretary be selected from the same country, in order to expedite the arrangements.

Mr. WATTEYNE. It seems to me that the Bureau of Mines should send officially to each government an outline of the project; this would be referred through the official channels to the testing stations.

Dr. CZAPLINSKI. I am afraid the use of diplomatic channels would take too long a time, perhaps ten years.

Mr. WATTEYNE. It should not take ten weeks. The representatives must be appointed by their respective governments. It is a question of form, but that form must be insisted on. The purpose of the committee must not be exaggerated. If it is exaggerated, you will find many objections. It must be understood that each testing station has to preserve its entire initiative and liberty of working for the best. Some points that have been investigated by the different countries are still in question and ought to be decided for the good of humanity. Certain testing stations are better equipped to make certain tests, which others could not make at all, and such tests will be arranged by the permanent committee.

Dr. BEYLING. I agree absolutely with Mr. Watteyne that the United States Government or the Bureau of Mines should write out the project and submit it to the other governments. I myself do not have the authority to decide matters for our Government. I can not say whether they want to participate in such an arrangement, but hope they do. I am convinced that they will. It must be done in an official way.

Mr. WATTEYNE. I do not understand that the requirements are that the different governments should be represented by only one person. There might be several. Each testing station might desire to be represented.

Dr. CZAPLINSKI. I was appointed by the department of public works as representative of the experiment station of Austria, and can not take any responsibility as to what the Government might desire. We have two stations and the third is being prepared. The two are private, and the new one will be governmental. The one in my district is a private station. I can not tell what the Government will do, but will try to influence it to adopt the requirements that we shall recommend, and try to see that the requirements are imposed on all the stations. I agree entirely with Mr. Watteyne's proposal that this project should come in an official way, addressed to the Government.

Mr. WATTEYNE. I think we should agree as to the details, but that this should not be communicated to the Governments, because it might cause complications. We should give them merely the principal objects of the organization.

Mr. O'CONNOR,^a after giving a historical review of the stations of Great Britain, including the establishment of an official station, at Eskmeals, stated that he thought the project a most desirable thing, and thought that the British Government would be perfectly willing to participate.

The meeting then adjourned for luncheon, with the staff of the bureau.

DEMONSTRATION OF MINING EQUIPMENT.

After luncheon, James W. Paul, mining engineer of the bureau, in charge of the bureau's mine-rescue operations, presented a paper on breathing and other rescue apparatus (see pp. 61-64), and gave an exhibition of rescue apparatus, safety lamps, etc., during which there was an informal discussion on the points brought forth by the exhibit.

H. H. Clark, electrical engineer of the bureau, exhibited various pieces of electrical apparatus, and demonstrated certain tests. He had prepared papers, which are presented on pages 68 to 75, but were not read as time was not available.

^a Although Mr. O'Connor was not the official representative of Great Britain, it was unanimously agreed that he should remain in the private session to assist in perfecting the plans for organization.

Clarence Hall, explosives engineer of the bureau, exhibited some of the apparatus used for testing explosives. During the demonstration further informal discussion took place.

The meeting then adjourned.

FOREIGN GUESTS AT BUREAU'S ANNUAL DINNER.

That evening (September 19) the foreign delegates to the conference attended, as guests of honor, the annual dinner of the staff of the Pittsburgh station of the Bureau of Mines, at which the director of the Bureau, Dr. J. A. Holmes, and the assistant director, Van. H. Manning, were present.

MINUTES OF MEETING OF FRIDAY, SEPTEMBER 20.

Mr. William O'Connor, as chairman, called to order the meeting of Friday, September 20. The minutes are presented below:

Mr. RICE. As this will be the last formal session, I think we had better first continue the discussion of permanent organization in order to be sure to arrange the details. As my colleague, Prof. Charles E. Munroe, has had to return to Washington, leaving me the only official representative of this country, I feel the need of instructions from the conference so that I may be able to report the matter to administrative officials of my Government.

Dr. CZAPLINSKI. I propose that we make two separate matters of it. I propose, first, that each experimental station, whether private or governmental, shall send representatives to the meetings. In addition to this, I propose that we shall have from time to time conferences to which each station shall be permitted to send a representative.

Mr. RICE. If it is in accord with the idea of having an interchange of information between the times of conferences, to whom should communications be addressed?

Mr. WATTEYNE. This was the first point, that each experimental station should have a representative in the organization, and to him communications should be addressed.

Mr. RICE. Would the communications go direct to him, or through the embassies?

Dr. CZAPLINSKI. The first communications should go through the governmental channels and subsequent one, no doubt, directly to the stations.

Mr. WATTEYNE. We can not determine now details of how communications should be sent.

Dr. BEYLING. At the preliminary meeting it was proposed to have the next meeting in England in 1914, but as England has no official representative we can not make any decision as to that point.

Mr. WATTEYNE. The first point to arrange is permanent organization. The Government of the United States has this to do—to write a letter in a diplomatic way stating the purpose and utility of the proposed organization, what has been done at this conference, and asking the Governments to appoint delegates to an international conference. The Governments will take the matter up with their testing stations and appoint the delegate or delegates. The matter of chairmanship and secretaryship is a matter that can not be taken up until later.

Dr. CZAPLINSKI. I agree thoroughly with Mr. Watteyne. In Austria communications should be addressed to the minister of public works, who will send the communications to a committee consisting of Government men.

Dr. BEYLING. There are two ways of treating this matter—first, to call meetings together through diplomatic channels; second, to have the various experimental stations arrange matters among themselves. It would be more practical to adopt this second way, as it is much simpler. It goes without saying that the various stations in each country should agree among themselves as to the organization of the general conference. If, however, the majority prefer that we proceed in the diplomatic way I will agree to it.

Dr. CZAPLINSKI. In Austria the committee can not do anything without asking the Government's permission. It is advisable, however, after the Government shall have given its permission to this organization that all further transactions and communications should go directly to the station.

Mr. O'CONNOR. As our British testing station has now been turned over to the Government it will be necessary to take the matter up with the Government. Sir Edward Grey is the minister of foreign affairs. He would send the matter through the proper channels.

Mr. RICE. As to the Canadian cooperation, should the matter be taken up through the home office, or direct with the Canadian representatives?

Mr. O'CONNOR. I believe that the Canadian station is entirely independent, and that the matter should be taken up direct with the Canadian authorities.

He suggested that the details be discussed and settled in order, as outlined in the New York meeting.

Mr. Rice offered a motion to the effect that it was the opinion of the delegates attending the conference that there should be a permanent organization of the mine-experiment stations of the various countries. This proposal was seconded and was unanimously adopted.

Mr. Rice then offered in the form of a motion the suggestions made in the preliminary conference, namely, that the chief purpose of the organization should be the discussion of plans and methods, the interpretation of the results of experiments, suggestions concerning special experiments that might be made most advantageously at different stations, and that there should be an interchange of samples and information.

Dr. Beyling thought that the unification of methods should be one of the main purposes, but that sufficient advancement had not as yet been made to establish the best method for certain investigations.

Mr. Rice thought that certain standards for comparison should be adopted; that although complete uniformity of methods could not be obtained, it would be desirable that as far as possible standards be adopted for comparison and future interpretation of results. Informal manifestations indicated the unanimous agreement of the conference.

Mr. WATTEYNE. When the committee is finally organized, every member who receives the appointment is to let the others know, and to send to the other delegates whatever publications his Government or station may issue, and put each other "en courant" of the work. When the delegates are appointed there will be no further necessity of using diplomatic channels. I agree completely with Dr. Beyling that it is only the first appointment that will have to be handled officially, and after that each member may do as seems best.

Dr. CZAPLINSKI. I agree entirely with Mr. Watteyne that it is sufficient to exchange publications. If we would send samples of coal dust, the composition might change during the time required to make the exchange. The railroads would not accept transportation of explosives.

Mr. Rice said that in view of the opinions expressed it might be better to drop temporarily the matter of exchange of samples, but that he was glad to note that all agreed to the exchange of information.

Dr. Czaplinski replied that he did not mean that certain samples could not be exchanged from time to time, as the occasion might arise, even if such exchange were not provided for in an agreement. He said that, for example, one station might test a new safety lamp in which other stations would be interested, and that the lamp could then be sent to the other stations.

Mr. Watteyne thought the section covering the matter might include "exchange of information and eventually other things."

It was finally agreed that the section should read as follows: "To further this purpose by the exchange of information, publications, and eventually of other material."

Mr. WATTEYNE. As to place of meeting, I would like to see the next one in England if it can be arranged. This was the opinion of those at the preliminary meeting in New York.

Mr. RICE. I propose that if this conference meets with the approval of the various governments, and if an invitation is extended from England, that those attending this conference approve the plan of having the next conference in England; if not held in England, that it be held in Belgium.

After a little discussion it was decided that the next conference should be held in 1914 if arrangements could be made by that time.

Mr. WATTEYNE. Belgium and France being so near to each other, we might perhaps arrange to visit Frameries and Liévin at the same time. I shall see M. Taffanel. If the next meeting can not take place in England I shall invite the conference to Belgium.

SUMMARY OF INFORMAL AGREEMENT AS TO FUTURE CONFERENCES.

A summary of the details agreed upon in the conference is presented below:

Name of organization.—International Conference of Mining Experiment Stations.

Chief purpose.—Discussion of plans and methods; interpretation and comparison of results of experiments; suggestions concerning special experiments that can be made most advantageously at different stations; and furthering these purposes by the exchange of information, publications, and eventually other material.

Method of organization.—After the official approval by the nations taking part has been given, each testing station, whether private or official, shall be eligible to take part in the conferences; but the re-

spective governments shall determine how the delegates shall be appointed to future conferences.

Time of meeting.—Each alternate year, at such date as may be agreed upon from time to time. If the conference is duly constituted as proposed, the first meeting is to be held in 1914.

Place of meeting.—For 1914 the meeting is to be held at the new English mine experiment station, if the plan is agreeable to the authorities in charge of that station; otherwise the conference is to be held in Belgium. Thereafter the place of meeting is to be agreed upon by a majority vote.

Method of voting.—Voting shall be by letter ballot, each participating country having one vote.

Officers.—The matter of officers for future conferences is to be settled after the approval of the several governments has been received. Meantime the secretary of the Pittsburgh conference, George S. Rice, is to assemble the papers and reports of discussions, with a view to their publication by the Bureau of Mines.

ADJOURNMENT OF CONFERENCE.

At the suggestion of Mr. O'Connor, a vote of thanks was tendered to the Bureau of Mines for its part in the conference. The meeting then adjourned sine die.

In the afternoon the members of the conference went to the experimental mine at Bruceton to witness the final coal-dust experiment, which was on a larger scale than the previous experiments. The explosion was very violent (see details on pp. 46-48), and the delegates were much interested in examining the effects of heat and violence within the mine.

CONFERENCE PAPERS.

A few of the papers read at the conference are presented at length in the following pages. Most of the papers, especially those dealing with topics that have been discussed in publications of the Bureau of Mines since the conference, are not given in detail, being merely summarized.

METHODS EMPLOYED BY THE BUREAU OF MINES IN INVESTIGATING COAL-DUST OR GAS EXPLOSIONS.

By GEORGE S. RICE.

ESTABLISHMENT OF THE BUREAU OF MINES.

In 1908, Congress appropriated funds for the investigation of the causes of mine explosions. This action was the direct result of the terrible loss of life in a number of great coal-mine disasters in January, 1907, which aroused public interest in the dangers of mining. The investigation was intrusted to the technologic branch of the United States Geological Survey, and in July, 1910, was transferred to the Bureau of Mines, established on that date, of which Joseph A. Holmes, formerly chief of the technologic branch of the Survey, was made director.

SCOPE OF THE BUREAU'S WORK AND ORGANIZATION.

The bureau's investigations, as developed by Director Holmes, may be classified under four heads, as follows: (1) Mine-accident investigations; (2) fuel investigations, relating to the production and use of coal, coke, oil, and natural gas; (3) investigations of mineral losses in mining, quarrying, concentrating, and metallurgical operations; (4) investigations of health conditions in the various branches of the mineral industry.

The organization of the staff of the bureau includes, besides an administrative division, under the director and the assistant director, and the engineer in charge at Pittsburgh, five technical divisions, as follows: Mining division, under the chief mining engineer; chemical division, under the chief chemist; mechanical division, under the chief mechanical engineer; division of mineral technology, under the

chief mineral technologist; and the metallurgical division, not yet fully organized.

In this paper only the work of the mining division that relates to mine accidents is discussed.

MINE DISASTERS.

Since 1908, each mine explosion in the United States involving loss of life and many mine fires have been investigated by the bureau's engineers. Early in the work rescue or oxygen-breathing apparatus was obtained for use in investigating explosions and for the possible rescue of entombed men.

MINE-SAFETY CARS AND STATIONS.

Railroad sleeping cars, of which there are now eight, were procured and equipped as mine-safety cars, to enable engineers and other employees to render efficient aid at disasters and to give lectures and training in the use of breathing apparatus and in first aid to the injured. The full crew of each car consists of a mining engineer, a foreman miner, a first-aid miner, and a cook. In remodeling the cars, lower berths in one-half of each car were removed to make room for storing apparatus, receiving visitors, and for training work in mining towns in which more suitable quarters are not available. The remainder of each car is divided into rooms—a kitchen, an office for the engineer, and a room for the foreman and first-aid man.

Besides the cars there are also six permanent training stations, including the Pittsburgh station, in different coal-mining districts of the country. These stations, each in charge of a mine foreman, are equipped with apparatus and have smoke rooms in which training may be given with breathing apparatus.

Through the bureau's activity thousands of miners have received training. Miners who take the complete course prescribed are given certificates. A further result of the training has been that the larger coal-mining companies have equipped cars and stations similar to those of the Bureau of Mines, and have trained miners.

When this work was first undertaken by the Government in 1908 only a few sets of modern apparatus had been purchased by mining companies. Now there are several thousand owned by private mining companies, and many training galleries have been established.

By the aid of breathing apparatus, the mining engineers and miners are able to investigate mines or parts of mines that could not be entered without it. Following explosions and mine fires, a number of lives have been saved. In the case of mine fires, the use of breathing apparatus has prevented loss of much valuable property by enabling men to attack the fires directly or to seal the fire areas.

FIRE-DAMP INVESTIGATIONS.

The geological as well as the chemical conditions governing the occurrence of fire damp in the mines of certain districts and the origin of methane and other mine gases are being studied. Gas samples for analysis have been gathered from mines in all parts of the country and investigations are being made to determine the relation of the outflow of gas to changes in barometric pressures and to the structure and composition of the coal.

DANGER FROM GAS WELLS.

In many mining districts of Pennsylvania, West Virginia, Illinois, and Indiana the coal measures are underlain with strata that contain oil and natural gas, the indiscriminate drilling for which constitutes a serious menace to the coal mines in those districts. Old wells are sometimes found in working the mine, and in a number of instances explosions or mine fires have been caused by the workings encountering gas wells. In some districts the wells are close together, and interfere seriously with the proper arrangement of the mine workings, for a pillar must be left around the well when its position is known. The natural gas found in the United States contains about 85 per cent of methane and 14 per cent of ethane. The chemists find that the inflammable mine gases normally do not contain ethane, so that ethane content is a strong indication of gas-well leakage. In certain instances this indication has possibly prevented disasters—proper changes having been made in the well casings to relieve the pressure or to prevent further leakage into the mines.

METHANE IN ANTHRACITE MINES.

Many of the mines in the Pennsylvania anthracite fields are very gaseous, the return air of a few of them occasionally having as high as 2 to 3 per cent methane. As much as 1,400 cubic feet per minute of pure methane, equivalent to about 28,000 cubic feet of fire damp, is found in the return air of some of these mines under normal conditions of working.

METHANE IN BITUMINOUS COAL MINES.

In the great bituminous coal fields of the United States the volume of gas issuing into the mines varies widely. In the interior coal fields there is practically none, except in a few mining districts. In the Rocky Mountain coal fields and also in the southern Appalachian fields some methane is found. In West Virginia and Pennsylvania the gaseous conditions vary widely. Possibly the most gaseous bituminous mines are in southwestern Pennsylvania, but in these the main returns rarely carry over 0.5 per cent methane. Even in the mines that are considered very gaseous, the percentage is generally

less than 0.3 per cent, although the return air from some parts of a mine may carry as much as 1 per cent of methane. The methane carried out by the air current from a so-called gaseous bituminous mine under normal conditions rarely exceeds 1,000 cubic feet a minute.

GAS ANALYSIS AS A GUIDE IN FIGHTING FIRES.

In fighting mine fires, and for determining whether an atmosphere is explosive, gas analysis has been found of the utmost value. Therefore mine-safety cars and rescue stations are equipped with portable apparatus of the Orsat type, as rearranged by G. A. Burrell, a chemist of the bureau. The samples are collected in glass bottles with ground-glass stoppers or rubber corks, a rubber bulb with tubes being used to fill the bottle with the sample. G. A. Hulett, chief chemist of the bureau, recently conceived the idea of taking such a sample in an evacuated flask or bulb in which the opening through the stem has been sealed by melting. When the sample is to be taken, a part of the stem is broken off at an annular filed nick. The gas rushes in, and then the small opening is sealed with wax. This method has proved successful. Samples gathered in the field, not requiring immediate analysis, as, for example, a sample from a mine fire, are put in containers and sent by mail to the Pittsburgh station.

It is generally conceded that the presence of a small proportion of gas renders coal dust extremely inflammable. The bureau desires to study in the laboratory and at the experimental mine the extent of this influence.

MINE-EXPLOSION INVESTIGATIONS.

Owing to mine explosions, the mine-fatality rate has been greater in the United States than in other large coal-producing countries; and unfortunately the rate for the past 10 years has been higher than in any previous decade. It is possible that the explosions may be attributed to the following causes:

1. The increased use of explosives in many western mines, and the practice of shooting off the solid without undercutting.
2. The failure to remove the fine dust made in undercutting with machinery before blasting.
3. The increased volume and velocity of the ventilating currents required by the larger number of miners employed in the average mine. One result of the increased velocity of the air current is that the fine coal dust is blown from the loaded cars as they pass through the entries, and another result is that the increased quantity of air dries the coal dust more readily.
4. The increased proportion of inflammable gas (methane) in the mine air, owing to the increased depth of the mines, and, in certain instances, to leakages of gas from wells.

5. The employment as miners of many unskilled men, a condition resulting from the tremendous expansion of the coal-mining industry, the output now amounting to over 450,000,000 metric tons annually.

6. The inability of many miners to speak English, and the consequent misunderstanding of orders given by English-speaking foremen.

7. Lack of discipline.

8. Lack of sufficient knowledge of gases and dust by foremen and fire bosses.

9. An insufficient number of foremen for the supervision of the work at the face and in other parts of the mine.

10. The great increase in the use of electricity. In 1910, 42 per cent of the total output of the bituminous coal and lignite was mined by machinery, and probably two-thirds of the machine-mined coal was mined by electric machinery. A large proportion of the hauling underground is by electric-trolley locomotives. The amount of coal thus transported is not known, but inspection would indicate that it is about one-half of the entire output. Many explosions have been attributed to electricity, especially those due to the use of trolley wires. Previous to 1902 electricity was little used.

RELATIVE RISK OF EXPLOSIONS IN THE UNITED STATES AND EUROPE.

The condition of the coal beds of the United States is generally much more favorable to mining operations than in Europe, except in the anthracite district of Pennsylvania and in some of the western fields, where the beds dip steeply. In the bituminous fields of Pennsylvania, West Virginia, Ohio, Indiana, and Illinois, from which the greater part of the output now comes, the beds are nearly level, lie rather close to the surface, and are generally freer from fire damp than the deeply buried and steeply inclined coal beds of Europe. On the other hand, the advantage of shallow, flat-lying beds introduces danger from coal-dust explosions. The coal is generally hard and requires undercutting, a process that produces fine dust. Moreover, the coal requires larger charges of explosives than the deeper-lying and more crushed coals of the European mines. In some mines, chiefly in the Middle West, the coal is not undercut but is shot "off the solid," a practice that requires excessive charges of explosives, produces much coal dust, weakens the roof, and is a frequent cause of blown-out or dangerous shots.

The passages, headings, or entries of most American mines follow the coal bed instead of cutting across them, as in the inclined beds of most European mines. Thus the walls of the passageways are of coal instead of rock or shale, the coal ribs tend to splinter, and the fallen coal is ground to dust by the feet or by the mine cars. Also, if an explosion has a good start, the coal-rib surfaces give off a certain amount of inflammable gas when struck by the hot flame of the explo-

sion, and it is even possible that the advance air wave tears off particles of coal from the walls, which may enter into the explosion, as after a violent explosion it is often found that the coal ribs are scoured as by a sand blast.

To summarize the comparison, there is much more inflammable gas in European coal mines as a whole, but coal dust is produced in much larger quantities in the American bituminous mines. On the other hand, the temperature of the average shallow American mine is not high, being generally less than 70° F. (21° C.), and the roof is relatively strong, so that there is less difficulty in watering the dust or in humidifying the mine atmosphere than in the European mines.

HUMIDIFICATION.

Humidification of the ventilating current has been introduced in many American mines since 1908 as a result of the experiments of the bureau and the study of the problem by American mining engineers. A widely adopted method is to humidify the entering air current in winter by steam jets. Such humidification immediately raises the temperature of the intaking air considerably, sometimes as much as 10° F., and at the same time supplies the needed moisture for producing a nearly saturated condition of the air. It has generally been found that if the average relative humidity of the entering air is maintained above 90 per cent the floor becomes damp and any falling coal dust becomes damp enough to stick together, so that it is not brought into suspension by an ordinary concussion. No coal-dust explosions have occurred in any of the mines in which humidification has been thorough, and there must be several hundred such mines. Extensive coal-dust explosions have occurred in mines in which imperfect sprinkling has been done by water car or by fixed sprinklers, or in which so small a steam jet has been used that the humidification has not been complete or continuous. It must be admitted, however, that large masses of coal dust are not readily wetted and should be loaded out of the mine.

ROCK OR SHALE DUST.

The use of rock or shale dust for preventing and limiting explosions, developed at the Liévin station, France, and at Altofts, England, has been tried in only a few mines. There are two reasons, as follows: (1) The bureau has not yet been in a position to thoroughly test the method at the experimental mine, and many operators in districts where water is scarce, or where wetting or humidifying injures the roof, are waiting for the results of tests to be made under American mining conditions; (2) roof shale sufficiently free from carbonaceous matter is not found as frequently in American as in European mines, where the levels cut the inclined strata. The absence of a suitable shale may be noticed at the experimental mine, where the shale

selected contained 8 per cent of combustible matter. On the other hand, there are limestone quarries near many coal-mining districts and the waste might be obtained at comparatively small cost.

DELIQUESCENT SALTS.

Crude calcium chloride is being used a little to supplement sprinkling by hose, or by water cars, and seemingly might be more used to supplement other means. It is of particular value in dampening the dust that settles in goaves or other places difficult of access which may be overlooked by the employee using hose or not reached by sprinklers. It may also be used to advantage in mines where the occasional wetting of gobs may lead to spontaneous fires.

RELATION OF THE WORK OF THE BUREAU TO STATE INSPECTION DEPARTMENTS.

Each State regulates mining operations within its domain; it makes its own laws and has its own inspectors. The State laws differ widely—some are detailed and specific, as are the Pennsylvania and Illinois laws; others are very incomplete and leave much to the discretion of the inspector. The Federal Government exercises no police control or supervision for safety in mining except in the Territory of Alaska. In those western States in which the Government owns the mineral rights of any land not yet sold the terms of sale are defined by the Land Office of the Department of the Interior, but the Government does not exercise any police supervision over the development of mines.

The United States Bureau of Mines does only investigative and educational work relating to various phases of the mineral industry. Its mining engineers have no power to effect improvements or changes in mining operations, or even to enter mines without the permission of the State authorities or the individual operators. However, the operators and State inspectors generally have welcomed the activities of the bureau and have freely permitted its engineers to enter mines and gather samples and make investigations. Many improvements that these engineers have been able to suggest have been adopted by the mine managers and owners.

Detailed reports of most mine accidents of any size and all mine explosions are submitted confidentially to the director by the engineers of the bureau. If the conditions are liable to lead to a repetition of the accident a confidential report is made to the mine operator. General reports covering each class of accidents are prepared by the bureau for publication in such a way as not to conflict with the reports of the inspectors of the various States. Later, it may be possible that those parts of the reports of individual mine disasters of scientific or educational value will be published.

EXPERIMENTAL MINE.

In 1910, the bureau decided to open a mine in which experiments relating to mine explosions could be conducted on a scale comparable with the operations of ordinary mining. The site finally selected, in December, 1910, is near Bruceton, Pa., 13 miles from Pittsburgh, on the Baltimore & Ohio R. R. The features considered in this selection were as follows:

1. The mine should be in a coal bed, like the Pittsburgh seam, in which inflammable dust is produced.
2. The coal bed at the place selected should be practically free from inflammable gas.
3. A natural-gas pipe line should be at hand to supply gas for experiments in the mine.
4. The mine should be free from dripping water and preferably self-draining, to permit experiments with dry coal dust.
5. The main openings should be drifts, to obviate the difficulties from shafts wrecked by violent explosions.
6. There should be a water supply for boiler use and for sprinkling or humidifying the mine.
7. The mine should be near a railroad to allow shipment of the coal, yet away from dwellings that might be damaged by explosions.

DESCRIPTION OF MINE.

The mine at this time (September, 1912) consists essentially of two main entries or headings, 1,260 feet long, driven in the Pittsburgh coal bed, and a diagonal heading 198 feet long, which intersects the air course at an angle of 55° at a point 117 feet from the mouth of the air course. A pair of left "butt entries" 210 feet long are turned at right angles to the air course at 850 feet from the main entrance. A single right "butt entry" 100 feet long is turned at right angles to the main entry at a point 775 feet from the main entrance. The total length of single entry is about 3,300 feet.

The mine is opened in a hillside, the crest of the ridge being 150 feet above the level of the entrances. The roof strata are chiefly carbonaceous shale. The entrances are of reinforced concrete, and for some distance inside the passages are lined with reinforced concrete, arched overhead. As finished, the width is 8 feet and the height of the crown above the floor 7 feet 6 inches. Where the entries are unlined the width is 9 feet and the height $6\frac{1}{2}$ to 7 feet. The main coal which is exposed in the ribs averages about $5\frac{1}{2}$ feet thick; above it is a 1-foot layer of soft "draw slate" or laminated shale, which is taken down in driving the entries; above this shale is a stratum of impure coal 6 inches to 2 feet thick; generally this forms an excellent roof, and does not require

support except where "rolls" (small faults) are encountered. The tracks laid in the entries are ballasted with roof shale, or with furnace cinders.

SHELVING FOR COAL-DUST LOADS.

For experiments with coal dust it was necessary to introduce artificial shelving, since the coal dust could not be as effectively placed upon the ballast of the floor as on the smooth floors of concreted or steel galleries; moreover, in winter, when the mine is dry, it is necessary to keep the floor moist and packed so that the finer road ballast may not be thrown into suspension by the violence of an explosion. There are five shelves made of 3 by 4 inch timber, with a 3-inch face upward on each rib. Where the entries are lined with concrete the shelves are held by bolts projecting from the lining; where the entries are unlined the shelves are bolted to posts recessed into the ribs and tied in by bolts and concrete.

INSTRUMENT STATIONS.

At 200-foot intervals along the main entry and the diagonal entry are large instrument stations, each lined with reinforced concrete, and divided by a strengthening wall, on one side of which are the instruments and on the other, guarded by a heavy steel door, is the entrance. The instruments are placed on a shelf, and connection with the atmosphere of the entry is through holes in a thick steel plate flush with the rib of the entry. These large stations are for pressure manometers, circuit breakers, and other automatic apparatus.

FLAME AND PRESSURE CIRCUIT-BREAKER STATIONS.

Halfway between the large stations are small stations or boxes for flame and pressure circuit breakers, so that the circuit breakers may be placed at 100-foot intervals. Access to each station is had by opening a hinged steel-plate door.

INSTRUMENT CABLES.

Electrical connections for the various instruments in the large and small stations are made by cables that run from the observatory outside of the mine to the main entrance, and thence through a 4-inch pipe placed behind the concrete lining or carried in a groove in the rib, which is faced with concrete. The cables enter each station (large and small), where they are cut and the individual wires fastened to binding posts on a board so that any desired connection can be made to the various instruments.

METHOD OF IGNITING SHOTS.

In some of the coal-dust explosion tests, the source of ignition has been by a "blown-out shot," prepared by drilling into the coal face

and lining the drill hole with a pipe; in others the igniting shot has been fired from a cannon. It is probable that the latter method will be used during the coming series of experiments in order to obtain a more regular initial pressure. Other methods of ignition, such as local gas explosions behind light brattices or bulkheads, may be tried.

SHOT-FIRING LINE.

The shot-firing lines are in the pipe carrying the other electric wires; immediately outside of the mine all of the wires are brought into a locked switch box. All switches are left open when men are in the mine preparing for an explosion test and the switch box is kept locked. When the men charging the igniting shot have come out, the switches are closed. At the observatory similar switches, also in a locked box, are closed. The keys of these boxes are carried by the men who charge and connect up the shot. When all connections are ready a button is pressed, completing the circuit, and thus firing the shot.

VENTILATING SYSTEM.

For ventilation while the mine is being developed, a small fan, capable of delivering 5,000 to 10,000 cubic feet of air per minute at 1 to 1½ inch water gage, is used. It is driven by a gas engine. During the first series of experiments, it was arranged as a blowing fan and was at the end of a 120-foot steel tube, in line with the diagonal heading. During the explosions the velocity of the ventilating current in the main entry was about 100 feet a minute, making the volume of air about 5,000 cubic feet a minute. This fan is now at the top of the small air shaft connecting with the air course, being used as a suction fan, the intake being through the main entry.

A large fan for experimental purposes (rated by the manufacturer as having a capacity of 80,000 cubic feet of air a minute with a 2-inch water gage, or 15,000 cubic feet of air a minute with 6-inch water gage) is driven by a 100-horsepower engine, through belting so that in case of sudden stopping of the fan by a violent explosion there will be less danger of wreckage. Reversing the fan is easily and quickly accomplished. This fan is near a branch of the external steel gallery, the connecting passage having two offsets with relief doors overhead and on the side, so as to afford full protection from an explosion. It is intended to run the fan without stop during an explosion, and to make some coal-dust experiments with the ventilating current moving first in one direction and then in the other, the influence of the direction of the air on the movement of an explosion being much debated by American mining men.

EXTERNAL STEEL GALLERY.

The external steel gallery is $6\frac{1}{2}$ feet in diameter and 122 feet long. A 20-foot section of the gallery, near the portal of the entry, may be rolled to one side, leaving detached from the mine a gallery that is almost a duplicate of the gallery at the Pittsburgh station, the exception being the branch that connects with the fan. This, however, may be shut off by a steel-plate diaphragm. This external gallery is for small-scale tests with different kinds of coal dust or of different methods of igniting coal dust or coal dust and inflammable gas. A track extends to the mouth of the gallery and connects with the track in the mine. The cannon is mounted on a truck so it can be easily placed at any desired point in the mine.

POWER PLANT.

The power plant is small, comprising a 60-horsepower locomotive-type boiler, room being left in the boiler house for a duplicate, and a small steam and electric generator set that produces 110-volt direct current for driving registering instruments and for some lighting.

WATER SUPPLY AND FIRE PROTECTION.

A small stream in the ravine in front of the mine has been dammed to provide water for boiler use and fire protection. A steam pump lifts the water to a 5,000-gallon tank on the hillside above the mine, the gravity pressure in the mine hydrants being 40 pounds per square inch. In the mine the water pipes are behind the concrete lining, and in the unlined section in the rib groove with the electric conduit. Valves and taps for hose are placed every 100 feet. The water is used for washing down the ribs, roof, and floor when needed, and for wetting the ballast when it becomes dry in winter.

COMPRESSED-AIR PLANT.

A small, single-stage air compressor, with a capacity of 174 cubic feet of air a minute at atmospheric pressure which will compress the air to 100 pounds per square inch, furnishes air for a punching machine used in driving the main entries. In the preparation for explosion experiments compressed-air jets are used for cleaning the shelves, roof, and ribs of burnt dust or soot.

PLANT FOR GRINDING ROCK AND COAL DUST.

Because of the large quantity of coal dust required in some tests the grinding plant is of fair size. The coal, as it comes from the mine, is dumped on a bar screen having 4-inch spaces; the larger pieces of coal are sledged through and fall into a hopper, which feeds a hammer

crusher. This crushes the coal to about $\frac{1}{4}$ -inch size or finer; the coal is then elevated to another bin, from which it is fed into a pulverizer or disintegrator having two blades that revolve in a steel-lined box at a speed of 2,700 revolutions per minute. The blades not only pulverize the coal or the shale, but act as fans. A suction fan above produces an upward current of air that lifts the finer particles of coal or shale through a conical separator provided with deflectors. The coarser particles drop back into the beater box and the fine dust passes upward through the fan to a "cyclone" collector. The excess air and a part of the lightest dust are discharged into an adjacent tubular collector, where a large number of cotton bags, or stockings, strain the dust from the air as the latter discharges through the fabric. From the two collectors the dust discharges into a storage bin. One great merit of the system is that as soon as the dust is fine enough it is lifted by the air current out of the disintegrator, and thus is less likely to lose gas through heating than in a grinding machine. Moreover, the coal is broken by impact rather than by attrition or grinding, either of which tends to produce local heating. The circuit is practically closed throughout except at the intake and the discharge through the stockings, so that there is no appreciable loss of coal dust, and the danger of igniting the coal dust in the grinding plant is reduced to a minimum.

From the dust-storage bin the ground coal or shale dust can be discharged into a mine car, or into cans placed in a car, for use in experiments.

COAL-HANDLING EQUIPMENT.

The small quantity of coal produced in enlarging the mine is loaded on ordinary mine cars of a type much used in the Pittsburgh district, and is hauled from the mine by mules or by gasoline motors, the latter being now (1912) under test. Outside of the mine the cars are hauled to a passing track, from which they are lowered by a rope down an incline to a small tipple at the railroad tracks. An internal-combustion (gas) hoisting engine pulls up the incline the empty cars and cars loaded with supplies.

OBSERVATORY AND CONTROL STATION.

The observatory, or control station, built of reinforced concrete, commands a view of the three entrances to the mine. The roof is made of railroad rails laid side by side and covered with concrete. The wall facing the mine is 2 feet thick, and has small windows. The external recording instruments—the chronograph, time markers, circuit-breaker recorder, and firing connections—are in the same building.

FIRST SERIES OF EXPLOSION EXPERIMENTS.

The opening test of the first series of coal-dust explosion experiments took place on October 24, 1911. The mine then consisted of two main entries, each about 700 feet long. Lack of funds that year (1911-12) prevented consecutive testing. In all there were 15 tests made. A full report of this series is now in the course of publication,^a so that the details are not discussed at length.

SUMMARY OF RESULTS OF FIRST SERIES OF COAL-DUST TESTS.^a

The chief conclusions from these tests were as follows:

(1) Explosions can be produced at will in underground passages having walls, roof, and humidity conditions typical of American mines.

(2) A blown-out shot in the coal face will raise in suspension coal dust placed on the floor or ribs, and will ignite it without a preliminary shot or concussion.

(3) Coal-dust explosions may be produced when the mine atmosphere is saturated and when the floors, ribs, and walls are damp, though not wet, provided enough dry coal dust is present.

(4) Although a coal-dust explosion often develops pressure and velocity slowly, it may reach a violent stage at less than 600 feet from its origin, and at that point may attain a velocity of 2,000 feet or more a second.

(5) The maximum pressures were not registered near the outlet, but 150 feet from the portal, although the dust load extended to the mouth, thus indicating measurable relief of pressure near the mouth.

PRESSURE-WAVE AND FLAME VELOCITIES.

The maximum pressure-wave velocity indicated by the pressure manometers and time markers was 1,954 feet per second, but the maximum flame velocity, indicated by the flame circuit breaker instruments, was 2,277 feet per second. The experiments were not numerous enough to warrant drawing conclusions as to the relation between the position of the flame and the forefront of the pressure wave.

MAXIMUM PRESSURES AT MANOMETER STATIONS.

The maximum pressure in the first series of tests in which the pressure manometers were in operation was recorded in the last experiment, 103 pounds per square inch being indicated at station 150, 150 feet from the mouth of the mine, whereas at station 50, 50 feet from the mouth of the mine, the maximum pressure was 60 pounds

^a Rice, G. S., and others, First series of coal-dust explosion tests in the experimental mine; Bull. 56, Bureau of Mines, 1913, pp. 66-113.

per square inch. A similar drop near the outlet was recorded in other experiments.

The maximum pressures mentioned above were probably not as high as those in one or two other tests in which the instruments failed to act properly. If the recorded pressures only be considered, the maximum pressures obtained in this first series were much less than those obtained by Taffanel in his surface gallery, and about the same as those obtained in the Altofts gallery. The number of experiments was insufficient for a complete comparison between the results at the experimental mine and those at the several surface galleries.

KIND OF COAL DUST USED.

The coal dust used in the first series of experiments came from a mine in the Pittsburgh seam about 10 miles from Pittsburgh, Pa. For future experiments the coal dust that will be used for the standard tests will be made from the run-of-mine coal produced in the experimental mine. The proximate analysis, averaged from a series of standard full-section face samples taken in that mine, is as follows:

Moisture.....	2.7
Volatile matter.....	36.0
Fixed carbon.....	55.0
Ash.....	6.3
	100.00

The average ultimate analysis is as follows:

Hydrogen.....	5.38
Carbon.....	76.16
Nitrogen.....	1.53
Oxygen.....	9.23
Sulphur.....	1.40
Ash.....	6.30
	100.00

Samples of the dust, for analysis, are gathered after it has been distributed, prior to each test.

INFLUENCE OF SIZE OF DUST.

M. Taffanel, in his experiments, has given much time and attention to the size of the dust used. In the bureau's preliminary tests made to determine the availability of mine passages for explosion experiments, the dust used was fine enough for about 95 per cent of it to pass through a 100-mesh screen (100 openings to the linear inch) and about 75 per cent through a 200-mesh sieve. This coal dust was ground at the Pittsburgh station in a small ball mill, as the grinding plant at the experimental mine had not been finished.

All investigators agree that the finest coal dust, when freshly mined, is the most explosive, but all sizes are found in coal mines in regular operation. Samples of road dust have been obtained in various mines of the country, and although gathered with care to exclude large pieces, when screened, as a rule, 50 to 75 per cent will not pass through a 20-mesh sieve. Previous gallery tests have indicated that the part passing through a 20-mesh sieve is the explosive part, but in making tests of the maximum dust dangers a finer dust should be used. Therefore the grinder will be set to produce dust that will pass a 100-mesh sieve. Such dust contains a large proportion of the finest sizes. In the tests to follow, the proportions of the different sizes will be exactly determined. The finest or lightest dust is first brought into suspension by a concussion; if more coal dust is used there is more of this fine dust in the dust cloud preceding the explosion wave.

OBJECTS OF THE COMING SERIES OF TESTS.

Briefly, the objects of the coming series of tests are:

(1) To study the conditions under which coal-dust explosions may start, and to determine the effect of different conditions, such as location, size of passage or chamber, temperature, humidity, and composition of dust.

(2) To study the propagation of an explosion, and to determine the effect of the conditions named, the arrangement of the mine, and coal-dust loading on the velocity of the explosion.

(3) To study the development of pressure and the relation of the pressure to the velocity and the temperature of the flame.

(4) To determine, if possible, whether an explosion with uniform dust loading, in a uniform passageway, constantly increases in velocity and intensity to the outlet; or, whether after the explosion has reached a certain velocity and intensity those manifestations become constant or fall and subsequently rise to another culmination.

(5) To study all promising means of preventing explosions from originating or propagating, such as humidification or use of rock dust.

(6) To study the means of checking or stopping dust explosions after once started.

(7) To determine the influence of ventilating currents as to direction and volume upon the propagation of an explosion.

(8) To study the influence of the temperature and humidity of the atmosphere on the starting and propagation of an explosion.

INFLAMMABILITY OF COAL DUST.

By J. K. CLEMENT.

Several methods for the laboratory study of the inflammability of coal dust have been used in England and in France. An apparatus devised for this purpose by J. C. W. Frazer, formerly chemist of the Bureau of Mines, consists of a glass bulb having a capacity of approximately 1,500 c. c., provided with tubulures at the top and bottom, and having an electrically heated platinum-wire grid above the lower tubulure and near the center of the bulb. A brass tube, closed at its upper end with a steel ball, communicates with the tubulure at the top of the bulb. Fifty milligrams of dust is blown through the lower tubulure against the glowing platinum grid, and the pressure developed by the explosion of the dust is measured by determining the smallest weight that must be placed on top of the steel ball to prevent its being lifted. The range of temperature of the platinum wire is 800° to $1,200^{\circ}$ C.

With this apparatus more than a hundred samples of coal dust from the various fields of the United States have been tested, in addition to samples of coal dust containing various inert substances, such as shale dust and sodium chloride. The results show that sodium chloride is more effectual than shale dust in reducing inflammability.^a

INSTRUMENTS USED IN COAL-DUST EXPERIMENTS.

By J. K. CLEMENT.

The instruments required in the investigation of coal-dust explosions in galleries are as follows: Gages or manometers for measuring pressure; devices for measuring the velocity of propagation of explosions; apparatus for taking gas samples.

PRESSURE APPARATUS.

Under pressure apparatus are included recording manometers and maximum-pressure gages.

^a A description of the apparatus and the results of the tests are given in "A Laboratory Study of the Inflammability of Coal Dust," by J. C. W. Frazer, E. J. Hoffman, and L. A. Scholl, jr.: Bull. 50, Bureau of Mines, 1913, 58 pp.

RECORDING MANOMETERS.

In a recording manometer the moving parts of the instrument must have small inertia and high frequency. In the manometers used at Altofts, England, the pressure acts against a steel spring, the movement of which is recorded, by means of stylus, on smoked paper carried on a rotating drum.

In the manometer used by Taffanel at Liévin, France, pressure is exerted against a steel membrane which is connected by a series of levers with a small rotating mirror. The movement of the membrane is recorded photographically.

In the manometer designed by the Bureau of Mines the pressure is transmitted by means of a plunger to a cylinder composed of a large number of thin carbon disks about 2.5 cm. in diameter. The variation in the resistance of the carbon-disk column, due to changes of pressure, is recorded by means of an oscillograph.

MAXIMUM-PRESSURE GAGES.

Maximum-pressure gages of the ordnance pattern have been used in the gallery tests at Liévin and in several tests at the experimental mine. In the latter tests the records obtained simultaneously on different gages at the same station did not agree. This disagreement was probably due to lack of care in the construction of the instrument cylinders.

INSTRUMENTS FOR MEASURING VELOCITY.

To determine the rates of propagation of flame and of the pressure wave, circuit breakers that are connected in series with a chronograph and operated either by flame or by pressure are placed at intervals in the gallery.

PRESSURE CIRCUIT BREAKERS.

In the pressure circuit breakers the circuit is broken by the action of pressure on a piston. In the tests at the experimental mine it was difficult to adjust the pressure circuit breakers so that they would be actuated by the pressure produced by the coal-dust explosion and not by the pressure from the blown-out shot. The pressure from the latter was found to be as great as 4 pounds per square inch at 100 feet from the shot.

FLAME CIRCUIT BREAKERS.

Two types of flame circuit breakers—the detonator and the tinfoil types—have been used. In some of the tests at the experimental mine, detonators coated with silver carbide were used. In

these tests the detonator type of circuit breaker proved to be unreliable, as the detonators were not always ignited by the flame. The behavior of the tinfoil circuit breaker was entirely satisfactory.

CHRONOGRAPHS.

For the B. C. D. chronograph used at Altofts, the circuit breakers are connected in series with the same electromagnetic recorder on the chronograph by means of an automatic commutator switch. At Liévin a chronograph with separate recorders for each circuit breaker is used. The objection to the first type of chronograph is that, when one circuit breaker fails to operate, circuit breakers placed to operate subsequently are not connected to the chronograph and therefore fail to record.

GAS-SAMPLING APPARATUS.

Satisfactory automatic instruments for taking gas samples during the passage of the flame have been designed in England and in France. A new gas sampler has recently been designed at the Pittsburgh station for the purpose of taking three samples in rapid succession during the passage of the flame.

REPORT OF EXPLOSION TESTS 16 TO 20 SEEN BY THE CONFERENCE.

By GEORGE S. RICE and L. M. JONES.

EXPLOSION TEST 16.

On September 12, 1912, in the preliminary test, the first of the second series made in the enlarged experimental mine, coal dust was placed on the side shelves in the outer 500 feet of the 1,270-foot main entry. Ignition was caused by a blown-out shot in a cannon such as is used in the explosives testing gallery in Pittsburgh. The axis is parallel with the floor and 24 inches above it. The charge prepared was $2\frac{3}{4}$ pounds of black blasting powder, tamped with 4 inches of clay stemming. The cannon pointed toward the mouth of the main entry, parallel with the axis of the latter. A platform of boards 5 feet wide was placed parallel with the axis of the cannon and 10 inches below it. This was loaded with 25 pounds of coal dust. Five hundred pounds of coal dust, or 1 pound per linear foot of entry, was placed on the shelving. That load was equivalent to about 0.26 ounce per cubic foot of gallery or entry space, or 260 grams per cubic meter. The coal dust used in this and the following tests was ground from coal mined from the Pittsburgh seam at the experimental mine, which is in the gas-coal

district. An average of analyses of dust samples taken from shelves before the tests is as follows:

Analysis of coal dust used in tests.

Moisture.....	2.49
Volatile matter.....	35.29
Fixed carbon.....	53.66
Ash.....	8.56
	100.00
Sulphur.....	1.20

More than 95 per cent of the dust passed through a 100-mesh sieve. The fan was running during the test; the air current returning in the main entry had a velocity of 166 feet per minute, so that the ignition occurred in the direction of the moving air.

When the shot was ignited in the usual manner by a button pressed in the observatory, smoke and flame issued from the mouth of the entry. The explosion was not loud, and was accompanied by little violence beyond the movement of dust and small particles flying. The flame extended 50 feet in by the cannon and out by to 175 feet outside the main opening, or a length of 675 feet from the cannon. No instruments were used in this test.

EXPLOSION TEST 17.

The second explosion test of this series was made on Saturday, September 14, in the presence of the delegates to the international mine-experiment station conference, Messrs. Watteyne, Beyling, Czaplinski, Monroe, and Rice, and Mr. O'Connor, unofficial representative. The experiment was similar to the first. Coal dust in the amount of 1 pound per linear foot was spread from the mouth to station 650. The cannon was placed at station 550, so that the dust load extended 100 feet in by its position. The cannon was charged with $2\frac{3}{4}$ pounds of FFF black blasting powder and 4 inches of clay stemming as in the previous test. A 16-foot bench with a load of 25 pounds of coal dust was placed in front of the cannon. The volume and direction of the ventilating current were as in the preceding test.

It had rained from 8.30 to 10.30 a. m., and the mine surfaces were much damper than in the previous test, being wet to the touch. There was standing water in the ditch extending along one side of the entry. The coal dust on the shelves had been in position an average of two hours before the test, and although the absorbed moisture probably did not affect to any great degree the explosibility of the coal dust when in suspension, it may have increased the adhesiveness of the dust, thus making more difficult the throwing of the dust into the air near the cannon.

When the shot was fired, coal dust was blown out of the mouth of the entry, but no smoke or flame issued. There was a muffled sound

of an explosion, slightly in excess of what would be caused by a shot alone. After an interval of two or three minutes the ventilating current brought out a considerable quantity of smoke, although not nearly so much as in the previous test. The pressure circuit breakers, which had been set at such a pressure that they would not be actuated by the shot itself, did not act. Examination showed that the gun-cotton tufts at 25-foot intervals had been ignited for 100 feet toward the entrance and for 50 feet inby against the air current. The result was of interest because it has been suggested that ignition inby could not be obtained from a shot pointed outby. No violence was manifest.

EXPLOSION TEST 18.

The third test was on Monday, September 16, in the presence of the foreign representatives and others. The igniting shot was fired from the cannon at the face of the right butt entry, 100 feet from the main entry. It had the usual charge of $2\frac{3}{4}$ pounds of FFF black blasting powder with $6\frac{1}{2}$ inches of clay stemming. Coal dust was loaded in the amount of 1 pound per foot from the opening to station 950, the latter point being 175 feet beyond the mouth of the butt entry. The loading in the butt entry was in the amount of 2 pounds per foot. The fan was drawing 9,500 feet of air into the main entry. The humidity of the current passing the butt entry was 92 per cent.

A cloud of smoke and dust issued from the main opening and a smaller cloud from the gallery explosion-door section. The plates and boards on the explosion-door sections and the door at the mouth of the air course were disarranged, but otherwise no damage was done. At E 1050 a car standing on the main entry was moved inby 10 feet. The guncotton tufts were consumed inby the butt entry to station E 1150, or 200 feet beyond the coal-dust load. The tuft at station E 100 was unburnt, but the one at station E 75 was gone, so that the flame or hot gases extended for probably 700 feet outby the butt entry, but did not reach the end of the coal-dust zone.

Depositions of coked dust were noted on the shelving and posts uniformly on the outby sides, both inby and outby the butt entry.

Manometer records were obtained at stations E 150 and E 250, but the pressure at station 550 was too low to be recorded. The maximum pressures at stations 150 and 350 were 3 and 8 pounds per square inch, respectively. The velocity of the flame from station E 750 to station E 650 was 97.3 feet per second.

EXPLOSION TEST 19.

For the igniting shot of the fourth test, made September 19, the cannon was placed at the face of the main entry, 1,270 feet from the mouth of the mine, and was charged with $2\frac{3}{4}$ pounds of FFF black blasting powder and 4 inches of dry clay. Coal dust was loaded on shelves throughout the main entry, the right butt, the crosscut at

station 1250, and from station A 1110 to station A 1160 at the rate of 1 pound per foot. A "Taffanel barrier" consisting of fifteen 20-inch shelves spaced 6 feet from center to center and loaded with finely ground shale dust was installed in the air course from station 1160 to station 1250.

Samples of air taken at the faces of the entries failed to show any methane. The humidity near the face of the main entry was 95 to 97 per cent. The volume of incoming air on the main entry was 8,800 cubic feet per minute.

When the shot was fired only a small cloud of dust appeared at the main opening. The flame extended only to station 1150, or 120 feet from the igniting shot. It passed through the crosscut and about 50 feet outby in the air course. Failure to obtain an extended propagation was probably due to the dust, which had become slightly dampened, not being raised as a cloud; and it is possible that the moisture on the surfaces of the entry and water standing in the side ditch along the entry may have cooled the igniting flame.

A second shot was fired after 200 pounds of fresh, dry coal dust had been scattered for 150 feet from the cannon. The flame did not extend any farther than in the previous explosion.

EXPLOSION TEST 20.

The explosion of the fifth test (Sept. 20, 1912) was originated as in the previous test at the face of the main entry. A charge of $2\frac{3}{4}$ pounds of FFF black blasting powder was placed in a hole drilled in the coal face and cased with $1\frac{1}{2}$ -inch pipe. In view of the wet condition of the mine, the cannon, loaded with a similar charge, was so placed in the crosscut that the flame would pass the outby corner of the crosscut and cross the flame of the shot in the face, an arrangement that miners term "cross firing." The coal-dust load was doubled. In addition to the 1 pound per foot previously used on the shelves, 1 pound per foot was scattered over the damp floor. This load extended throughout the main entry, through the right butt entry, and through the crosscut at station 1250 into the air course where a Taffanel barrier was placed, extending from the crosscut for 60 feet outby; outby this, 50 feet of coal dust was placed to show whether the flame would pass the barrier. Including the coal dust strewn on the damp floor there was about 0.56 ounce per cubic foot of (entry or gallery) space or 560 grams per cubic meter. A total of 3,000 pounds of coal dust was used in the loading. This dust was from the run-of-mine coal. A screen test gave the following results:

Percentage passing through screen.	Mesh.
100.....	80
97.5.....	100
93.3.....	150
75.9.....	200

The Taffanel barrier consisted of 10 shelves 20 inches wide heaped with shale dust. A feature unintentionally introduced, which may or may not have increased the efficiency of the stopping, was the closing of a light door across the crosscut at station 1250, and probably did not affect the velocity of the explosion wave passing into the air course where the barrier was placed.

It had been decided to make the explosion in quiet air, without moving current, by shutting off the air outby the explosion area in the air course and closing a door in the crosscut. This door and its frame were totally destroyed in the explosion.

The humidity at the face was 92 per cent.

An immense cloud of smoke and dust, accompanied by a loud report, issued from the main opening a few seconds after igniting shots had been fired. When the cloud had traveled to the end of dump, the flame shot out of the opening and disappeared in the cloud 100 feet from the opening.

An empty mine car standing 50 feet from the opening was hurled over a truck (a mine car without sides) that had been standing 50 feet beyond and landed, bottom up, in the field opposite, 210 feet from its first position; from there it bounded 21 feet to an upright position. The truck was thrown off the track 75 feet from its first position. Two small telegraph poles, 50 and 100 feet from the opening and 4 feet east of the center line, were broken off near the ground and one was hurled 294 feet into the field opposite.

Considerable damage was done inside the mine. The concrete along the springing line was badly cracked and in a number of places the cracks extended across the arch. At a point 74 feet from the mouth of the entry the old concrete arch was lifted and remained 8 inches higher than a later arch that had been built beneath it. The posts and shelves in front of all of the crosscuts were torn out. The shelving from a point 650 to a point 700 feet from the entrance was thrown down and that from point 775 to point 850 was torn apart. Three posts were found to have gone inby to points 834 and 1025, one being moved from its former position fully 235 feet in a direction opposite that of the explosion. The face of the entry was half covered with a pile of broken boards and blocks that had been thrown into the face. The cannon in the crosscut was moved back against the rib.

The Taffanel barrier was thrown down, the shelves broken into small pieces, and the shale dust from the shelves distributed along the air course for a considerable distance. The flame passed through the crosscut but not beyond the barrier.

The 18-inch brick stopping in a crosscut at 850 feet was blown out and some of the bricks were thrown into the No. 1 left butt entry opposite, as far as the face, 235 feet distant, and others were carried 150 feet outby in the air course. The water from a pool on the air-

course side of this stopping had been thrown in the air course outby the crosscut.

The track in the air course opposite the cut-through was torn up and bent toward the No. 1 butt entry. Shelves and ties were broken by flying bricks. Track ties were disarranged for 100 feet in this butt entry.

In the main entry the maximum pressures registered by the manometers in the stations 550, 350, and 150 feet from the mouth of the mine were 34, 114, and 88 pounds, respectively, the highest pressure not being recorded by the manometer nearest the mouth.

SPONTANEOUS COMBUSTION.

By HORACE C. PORTER.

Experiments in which powdered coal was heated to 100° C. in a current containing 50 per cent oxygen have proved that the process of absorption of oxygen by coal (not producing CO₂) is exothermic. Furthermore, the carbonaceous material absorbs oxygen more rapidly than does pyrite, thus showing that the oxidation of pyrite is not the principal factor in spontaneous combustion.

Coal subjected to this action, the absorbing of O₂ without forming CO₂, decreases in calorific value, which is another evidence, as Taffanel has pointed out, that the action is exothermic.

Coal artificially dried, or even partly dried, will recombine with water, with evolution of heat. Fifteen grams of coal dried at 100° C. was exposed in a crucible to the air of the room, and in 15 minutes its temperature rose from 25° to 31° C. When a few drops of water were added, the temperature rose quickly to 38° C. More precise experiments showed that this coal, when partly dried, so as to contain 2 per cent water, developed, on being moistened, 14 calories per gram. Hence, at least a part of the moisture of coal (expelled by drying at 100° C.) is held in a form of hydration, not as free moisture. In some coals this rehydration after incomplete drying may contribute to the initial spontaneous development of heat.

THE DISTILLATION OF COAL.

By HORACE C. PORTER.

In 1908 to 1910 experiments^a were made to compare the composition of the volatile products obtained from different types of coal at different maximum temperatures. These experiments, though

^a Porter, H. C., and Ovitz, F. K., The volatile matter of coal: Bull. 1, Bureau of Mines, 1910, 56 pp.

they were imperfect and unsatisfactory in that they involved a somewhat gradual heating of the coal from room temperature to the maximum in each test, and also considerable uncertainty because of secondary decomposition of the volatile products by passage over heated surfaces, served, however, to bring out differences in the volatile matter of different coals.^a

The results show the following facts applicable to the study of coal-dust explosions and possibly other mining problems:

(1) The volatile products are not entirely composed of combustible matter; the noncombustible or inert constituents are a large and important part of the volatile matter from some coals, as shown in the table below:

Comparison of volatile matter and combustible volatile matter from four American coals.

Source of coal.	Volatile matter including moisture.	Volatile matter without moisture.	Combustible volatile matter.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Pocahontas, W. Va.....	21.4	20.9	17.8
Pittsburgh bed, Pa.....	31.8	30.7	26.0
Zeigler, Ill.....	37.9	30.4	21.9
Sheridan, Wyo. (subbituminous coal).....	50.0	38.8	17.1

The inert constituents of the volatile matter are largely water of composition and CO₂.

Although the proportion of volatile matter may be in some degree a measure of the inflammability of a coal, inflammability may depend not so much on the percentage of volatile matter as on some other factor which varies as the volatile matter. Certain coals that have a high volatile-matter content and are highly inflammable yield, on the other hand, a relatively small amount of combustible volatile matter and a large amount of the noncombustible, deadening materials, CO₂, and water, which would be likely to lessen the inflammability of the volatile products. The table below shows the results of heating 10 grams of the four coals mentioned above for 10 minutes to a maximum temperature of 600° C.

Combustible ingredients of volatile matter from four coals (not including CO and ethylene hydrocarbons).

Sources of coal.	Tar.	Higher homologues of CH ₄	CH ₄ and homologues.	Hydrogen.
	<i>Per cent.</i>	<i>C. c. per gram.</i>	<i>C. c. per gram.</i>	<i>C. c. per gram.</i>
Pocahontas, W. Va.....	4.4	11.0	41.5	19.1
Pittsburgh bed, Pa.....	11.5	19.4	48.4	21.0
Zeigler, Ill.....	8.2	6.8	29.6	15.7
Sheridan, Wyo.....	8.6	7.5	28.0	16.6

^a Since the conference the bureau has designed an apparatus with which a sample of coal may be quickly heated and the volatile products may be quickly withdrawn over cooled surfaces.

The results support the conclusions drawn above from the first table on page 49. The high-volatile Wyoming and Illinois coals yield less inflammable gas than the Pocahontas and Pittsburgh coals and less tar than the Pittsburgh, although inflammability tests seem to show that the Wyoming and Illinois coals are the more inflammable.

(2) Although the volatile matter distilled from coal during momentary heating in a coal-dust explosion is doubtless a factor in the ignition of the dust, or in the propagation of the explosion, other phases of the chemical character of the coal are probably important.

(3) The highly bituminous coals, such as those of the Pittsburgh bed, decompose on moderate heating (not over 600°C.), so as to yield volumes of C_2H_6 and other CH_4 homologues nearly equal to that of CH_4 . All the coals tested give a large yield of these higher hydrocarbons on moderate heating. The high heat of combustion of these hydrocarbons and their low inflammability limit may have an influence on the inflammation of dust.

These facts also lead to the theory that different coals contain different proportions, first, of substances yielding "paraffins" on distillation, and, second, of substances yielding chiefly CO_2 , CO , and water on distillation.

ESCAPE OF GAS FROM COAL.

By HORACE C. PORTER.

Coarsely broken coal from some mines, if placed in bottles as soon as possible after mining and kept at ordinary temperature and pressure, liberates a remarkable volume of methane. Practically the same amount of gas is set free at atmospheric pressure as in a vacuum.

The gas liberated is largely CH_4 . A little CO_2 was found, but no CO , H_2 , or higher homologues of CH_4 (within the limits of error of the analysis).

The various coal types varied widely in the amount and rate of gas evolution.^a No definite connection was observed between this tendency and the composition of the coal.

The largest evolution of CH_4 was 0.67 liter per kilogram of coal in 50 days, from a southern Illinois coal from a region where the mines are decidedly gaseous.

The tendency of a coal to set free inflammable gas, even though the coal be not finely powdered, must add materially to the danger of gas

^a See Porter, H. C., and Ovitz, F. K., The escape of gas from coal: Technical Paper 2, Bureau of Mines, 1911, p. 11.

or dust explosions in mines. Not only the suspended dust in the atmosphere of the mine, but also the coarsely broken coal that lies on the floors, continually liberates gas. In poorly ventilated parts of the mine the accumulations of gas may become dangerous.

WEATHERING OF COAL IN THE BED.^a

By HORACE C. PORTER.

Samples of coal were taken at intervals along the entries at the experimental mine, according to the standard method used by the Bureau of Mines.

The analyses of these samples computed to the ash-free and moisture-free basis show that the coal is abnormally low in C and H and high in O for a distance of 35 to 40 feet from the outcrop. Beyond that point there is little variation, and the composition is normal.

A few samples were reduced to dust and compared as to inflammability. Coal taken 50 feet from the outcrop showed practically no difference from coal 600 feet from the outcrop, but coal 1 foot from the outcrop was much less inflammable. The outcrop sample absorbed oxygen and liberated methane much more slowly than did fresh coal from 600 feet in. The coal at 50 feet in showed, in these respects, some effect of weathering.

Seemingly weathering has not materially affected the chemical character of the Pittsburgh coal at the experimental mine more than 40 to 55 feet from the outcrop.

THE OXIDATION OF COAL.

By HORACE C. PORTER.

The experiments made to show the escape of methane from coal incidentally called attention to the rapid absorption of oxygen by coal at ordinary temperatures. The rate of absorption seemed to be affected by the percentage of oxygen in the atmosphere surrounding the coal and, of course, by the kind of coal and its fineness of division.

The possibility that this absorption may be surface condensation, as with charcoal, seems to be precluded by the fact that the oxygen

^a Porter, H. C., and Fieldner, A. C., Weathering of the Pittsburgh coal bed at the experimental mine near Bruceton, Pa.: Technical Paper 35, Bureau of Mines, 1914, 35 pp., 14 figs.

absorbed could not be liberated again from the coal either in boiling water or in a vacuum at high temperatures. The absorption increases rapidly as the temperature rises. Only slight amounts of CO_2 are produced.

More precise experiments on finely powdered coal (80 to 100 mesh fineness) exposed to the action of pure oxygen at a constant pressure approximately as that of the oxygen in air, have shown remarkable variations in the rate of oxygen absorption by different coals.

Those coals that show strong tendencies toward inflammability, deterioration, and spontaneous combustion appear to have the highest rates of oxidation. These are the types, generally speaking, that contain a high percentage of oxygen. This coefficient of oxidizability may be an important factor in the inflammability of coal dust.

INFLUENCE OF CARBON DIOXIDE ON THE EXPLOSIBILITY OF MINE GASES.^a

By J. K. CLEMENT.

Experiments to determine the influence of carbon dioxide on the explosibility of methane have been made with two objects, as follows:

(1) To determine what proportion of carbon dioxide would have to be added to a mine atmosphere to render it nonexplosive.

(2) To furnish data on the explosive limits in mixtures of methane, oxygen, nitrogen, and carbon dioxide, with which to interpret the results of analyses of mine gas.

The experiments, which were made in a gas-explosion pipette and in a steel cylinder with a capacity of about 2 liters, show these results:

1. The limits of explosibility depend greatly on the kind of ignition used.

2. A mixture of air and carbon dioxide containing 22.5 per cent CO_2 or more will not form with natural gas a mixture that is explosive in a gas pipette, with the ordinary type of spark gap.

3. By replacing the nitrogen of the air with carbon dioxide, it was found that when 95 per cent of the nitrogen was thus replaced no mixture of natural gas would explode in the gas pipette. Hence carbon dioxide, when present in mixtures of natural gas and air, reduced the explosibility of the mixture to a much greater extent than did the same volume of nitrogen. As carbon dioxide does not react chemically with any of the constituents of the mixture, under

^a Clement, J. K., *The effect of inert gases on the inflammability of gaseous mixtures*: Technical Paper 43, Bureau of Mines, 1913, 23 pp.

the conditions of the experiment, the dampening action of carbon dioxide is probably to be attributed to its high specific heat. The mean specific heats between 0° and 650° C. of carbon dioxide and nitrogen are respectively 10.6 and 7.2.

4. As might be expected, wider limits of explosibility were found in the steel cylinder with an arc from a 220-volt circuit than with the spark from the induction coil.

THE SAMPLING AND CHEMICAL ANALYSIS OF COAL DUST.

By A. C. FIELDNER.

The analysis of a complex and somewhat unstable substance like coal dust is beset with difficulties.^a The determination of the chemical elements composing the dust is a precise analytical operation that can be duplicated by different chemists, and thus afford comparable data, but to have comparable determinations of moisture, ash, volatile matter, and fixed carbon the procedure must be made strictly uniform. Hence, it is important to obtain by international cooperation the adoption of uniform methods for the proximate analysis of coal, and thus permit direct comparison of the analytical data relating to inflammability investigations.

To avoid moisture changes during sampling and analysis, it is the practice of the bureau's investigators to air-dry all samples of coal and coal dust immediately on opening the original sealed container in which the sample has been transported to the laboratory. The loss in weight on air drying is recorded and the analysis of the air-dried sample is computed to the "as-received," as well as to a dry and to a moisture-free and ash-free basis. After the sample has been air dried it is at once passed through a set of rolls that pulverize it to 10-mesh size, is rapidly mixed and reduced in an inclosed riffle sampler to 500 grams, which is placed in the porcelain jar of a pebble mill and sealed air-tight. The mill is rotated until the sample is of sufficient fineness to pass through a 60-mesh sieve. The laboratory sample of about 60 grams is preserved in a rubber-stoppered glass bottle. In this manner there is obtained for analysis a sample in which the moisture content is in approximate equilibrium with the atmosphere and consequently will undergo the minimum moisture change in the time required by the analyst for weighing his sample.

^a For detailed methods of coal analysis see Stanton, F. M., and Fieldner, A. C., *Methods of analyzing coal and coke*: Tech. Paper 8, Bureau of Mines, 1913, 42 pp., 12 figs.

Many experiments have shown this method of preliminary air drying and pulverization in the inclosed pebble mill to be more accurate than any other practical method.

PROXIMATE ANALYSIS—DETERMINATION OF MOISTURE.

Moisture in the air-dried sample is determined by heating 1 gram of the sample, placed in a shallow porcelain capsule, for one hour at 105° C. in an oven through which is passed a current of dry air. The air is dried by being passed through sulphuric acid. The sample is then cooled in a desiccator over sulphuric acid and weighed. Loss in weight is reported as moisture. This method for the determination of moisture, although not as accurate as drying in a vacuum or in a current of inert gas, is in rather general use both in this country and in Europe.

There is, however, one essential difference between the bureau's method and the usual technical method. In the oven an atmosphere of air dried by having been passed through sulphuric acid is maintained. The extent to which a coal sample can be dried by heating varies with the humidity of the surrounding atmosphere. In the ordinary air bath, with stagnant air, the humidity will vary from day to day, being dependent on atmospheric conditions, and will vary also with the quantity of moisture coming from the samples in the oven. A number of experiments have shown that the circulation of dry air through the oven chamber gives higher and more concordant results than heating in stagnant air.

DETERMINATION OF ASH.

Ash is determined by igniting the sample in a muffle maintained at a temperature of about 750° C. The part of the mine-section sample previously used in the moisture determination is used in the determination of ash. Here again there is an opportunity for disagreement between different laboratories, especially with coals containing notable quantities of calcium carbonate and iron pyrite. On ignition the calcium carbonate is decomposed and carbon dioxide driven off, either partly or completely, depending on the temperature. The iron pyrite is changed to ferric oxide, and, in the presence of lime, calcium sulphate may be formed. Experiments with a certain Illinois coal have given an ash percentage of 14 per cent by ignition to constant weight and complete combustion of carbon at a low red heat, whereas at a bright yellow heat only 12.5 per cent ash was obtained. Therefore, there should be a standard temperature for the ash determination.

DETERMINATION OF VOLATILE MATTER AND FIXED CARBON.

Volatile matter is determined by heating 1 gram of the air-dried coal in a well-burnished, 30-gram platinum crucible, closed with a well-fitting cover, for exactly 7 minutes over the full flame of the No. 3 Meker burner. The crucible is supported on a platinum triangle so that the bottom of the crucible is 2 cm. above the top of the burner. The orifice of the burner is adjusted so that the free-burning flame is 17 to 20 cm. in length. The temperature attained in the crucible is about 950° C. The loss in weight, less moisture, is called volatile matter.^a

This determination is purely arbitrary in character, and duplicate results are attained only by a rigid duplication of conditions. The method used by the bureau is essentially that recommended by the American Chemical Society committee on coal analysis.^b It is modified in that the Meker burner is used in place of the Bunsen.

ULTIMATE ANALYSIS.

The ultimate analysis of coal dust affords no particular difficulty. The usual method of combustion in a current of oxygen is followed. The products of combustion are passed over red-hot copper oxide to insure complete oxidation and over lead chromate to remove the sulphur. The water and carbon dioxide produced are absorbed in calcium chloride and caustic potash, respectively.

For the determination of combustible or organic carbon in stone dust or shale the following method is used: The pulverized sample is evaporated to dryness on the water bath with hydrochloric and hydrofluoric acid, this treatment being repeated twice. The residue is then taken up with hydrochloric acid, digested, filtered on ignited asbestos, transferred to an oven and dried at 105° C., and then immediately placed in the combustion furnace and carbon and hydrogen determined in the usual manner. The hydrofluoric and hydrochloric acid treatment decomposes the inorganic carbonates and hydrous silicates, from which the water of composition is then removed by drying.

DETERMINATION OF NITROGEN.

The nitrogen is determined by the Gunning-Arnold-Dyer modification of the Kjeldahl method. No difficulty is experienced in obtaining accurate results.

^a Since this paper was written, the apparatus for determining volatile matter has been changed to an electrically heated crucible furnace, which, by means of a thermocouple, is maintained at 950° C. The coal is heated in a 10-c.c. platinum crucible which is closed by a capsule cover. More concordant results are obtained than with the former method.

^b Noyes, W. A., Hillebrand, W. F., and Dudley, C. B., Report of committee on coal analysis: Jour. Am. Chem. Soc., vol. 21, 1899, p. 1116.

DETERMINATION OF CALORIFIC VALUE.

Determination of the calorific value is made with the Mahler bomb calorimeter. The Bureau of Mines follows the usual American practice of recording the gross heating value—that is, with all products of combustion cooled to the temperature of the calorimeter.

DETERMINATION OF SULPHUR.

Sulphur is determined by the Eschka method. Accurate results are obtained.

RESULTS OF EXAMINATION OF COAL DUST UNDER THE MICROSCOPE.

By REINHARDT THIESSEN.

PURPOSE OF EXAMINATION.

In the microscopic examination of coal dust, either as road dust, rib dust, or in the artificially ground form, many important details may be observed. Many of these lead to further investigation, the results of which lead to important conclusions bearing on the explosibility of coal dust.

RELATIVE SIZE AND NUMBER OF PARTICLES.

In coal dust that will pass through a 200-mesh screen a comparatively few of the largest particles measure about 50 to 70 microns in diameter. From this size down all imaginable sizes to ultramicroscopical particles are found, and the smaller the size the larger the number. The limit of visibility with ordinary illumination is reached with a size of about 0.25 micron. The number of particles still visible in any given field under the microscope with ordinary illumination is enormous. If when a 1 per cent mixture of coal dust and Canada balsam is placed under a microscope field with medium magnification the largest particles can be counted by units, those particles that are just within the range of ordinary microscopic vision must run up toward the millions. Under a magnification of 2,000 diameters it was impossible to count them in any given field. Although the smallest particles visible have a diameter of about 0.25 micron, it is fair to assume that there are countless smaller particles. In fact, ultramicroscopic investigation reveals an enormous number of particles not visible with ordinary microscopic observation. Unfortunately, however, there was no adequate means at hand to determine their number. It can readily be seen that the number of particles in a cubic centimeter of coal dust is enormous—almost beyond comprehension.

FORM AND STRUCTURE OF PARTICLES.

Most of the particles are angular, many approximating cubical, tetrahedral, or polyhedral forms, some having rather smooth edges and surfaces, others being irregular, and many showing numerous irregular concave and convex surfaces. The specific surface of all of them is much greater than that of a sphere, and of the majority is larger than that of a cube.

Furthermore, in observing minute particles of extremely thin coal sections, with proper dark-ground illumination, or other ultramicroscopic means, it is found that most of the particles that, under ordinary microscopic vision, appear as if perfectly glassy or homogeneous are spongy, or as if composed of a large number of micellæ; in other words, it is shown that they are not homogeneous solids, but are highly heterogeneous.

BROWNIAN MOVEMENT.

Another point that deserves especial attention is the Brownian movement of the fine dust particles. It is phenomenally active alike in water, alcohol, or xylol. Even in Canada balsam it is pronounced. The amplitude is particularly large and the translatory speed high. The motion is not confined to very fine particles, but may be noticed in rather large ones; that is, particles of a size that, in other bodies, would show no movement at all here show active movement. As the cause of this phenomenon has never been satisfactorily explained, no reason for such great activity in coal dust can be given, but it must be significant.

On the dry dust the minute particles tend to aggregate in small lumps, and also a great number adhere to larger particles.

A microscopic examination of coal dust shows that it contains particles ranging from coarse to colloidal. Furthermore, the larger proportion of the particles, if not all of them, are not true solids, but are grouped into heterogeneous masses, probably in a biphased condition, with solid-gaseous surfaces of separation.

A microscopic examination of coal dust screened with a 200-mesh screen shows that the sizes range from 70 microns to an ultramicroscopic size—certainly below 0.25 micron; also that the smaller the particles the greater their number. As the specific gravity of Illinois coal is about 1.55, 1.55 grams of coal dust, if the particles be assumed to measure 1 micron, would represent approximately one trillion particles, with an absolute surface of certainly more than 6 square meters and a specific surface of 60,000; and if the particles be assumed to be 0.1 micron in diameter, there would be approximately one quatrillion of them, with an absolute surface of 60 meters and a specific surface of 600,000.

ABSORPTION PHENOMENA.

Platinum sponge glows when exposed to hydrogen because the hydrogen is condensed upon a film of condensed oxygen. Charcoal freed from air will absorb 60 to 80 times its volume of CO_2 . Meerschäum, fuller's earth, and powdered glass exhibit similar phenomena.

Mixed gases are absorbed more slowly than is a pure gas; one gas is able to suppress a second already absorbed, and the equilibrium is often reached only after days. In a mixture of two gases both are absorbed; the one that is absorbed most when alone is absorbed most from the mixture. Much of the nature of the absorption depends upon the gas or gases already present; it is also certain that the nature of the gas absorbed is of much greater importance than the chemical nature of the absorbent.

The foregoing discussion leads to an inquiry as to whether coal dust may show the same phenomena. Experiments have been made by the bureau's investigators, but the figures so far obtained are not altogether reliable, although enough has been done to show that coal dust should be classed with charcoal, meerschäum, fuller's earth, etc., as regards gas absorption.

The bituminous coal from Sesser, Ill., used for the experiments was ground to 200-mesh fineness, no precaution being taken to keep it from the air. Natural gas, oxygen, carbon dioxide, hydrogen, and ammonia were used in the test, no attempt being made to remove gases already absorbed by the dust.

7.688 grams of dust absorbed 32.5 c.c. of natural gas. In an average of three experiments $\frac{V}{M} = 5.6$, in which V is the volume in c.c. of gas absorbed and M the weight of coal in grams.

After equilibrium had been established the natural gas was replaced by dry ammonia until the equilibrium had again been reached. The total volume of ammonia absorbed amounted to 261.3 c.c. In this case $\frac{V}{M} = 44$.

The absorption of oxygen and carbon dioxide was small, probably because the dust was already well saturated with both gases.

The absorption of hydrogen in 6.88 grams of coal dust was 11.3 c.c.

These experiments must be considered as preliminary only. More accurate apparatus must be devised to procure reliable results.

SAMPLING AND ANALYSIS OF MINE GASES.^a

By G. A. BURRELL.

SAMPLING MINE GASES.

Hitherto most of the mine-gas samples taken by the bureau have been collected with the aid of small rubber syringe bulbs. Under the present method of sampling, glass containers are exhausted at the laboratory by means of a vacuum pump and are sealed in a flame. At the place in a mine where the gas sample is to be collected a capillary glass-tube extension on the container is broken and the mine air fills the container. The broken end of the container is sealed with a small piece of soft wax.

When a sample is collected, all data pertinent are recorded, such as wet and dry bulb reading, barometric reading, velocity of air current (if sample is taken in the moving air), and cross section of area. Most of the containers have a capacity of 300 to 350 c. c. All samples are collected in duplicate.

ANALYSIS OF MINE GASES.

Haldane's apparatus, slightly modified, is used for much of the analytical work. Carbon dioxide, oxygen, methane, carbon monoxide, and hydrogen can be determined with an accuracy of 0.01 or 0.02 per cent. When more than one combustible gas is present, a determination of the excess oxygen is made. Carbon dioxide is determined by caustic potash absorption, oxygen by alkaline pyrogallate absorption, and the combustible constituents by the slow-combustion method. The Haldane apparatus is used for those mixtures containing less than about 5 per cent methane.

The iodic acid method for carbon monoxide is used for checking the carbon monoxide determinations made with the Haldane apparatus and for the determination of smaller quantities of carbon monoxide than can be detected with that apparatus. As ordinarily used for the determination of small quantities of carbon monoxide—0.3 per cent and less—it has been found that mine air vitiated by explosions, explosives, and gasoline motors, and containing such small quantities of carbon monoxide, does not usually contain olefin hydrocarbons or other gases that reduce the iodine pentoxide in sufficient quantity to necessitate a more complicated train than one consisting of caustic potash solution, sulphuric acid, and calcium chloride.

^a See Burrell, G. A., and Seibert, F. M., The sampling and examination of mine gases and natural gas: Bull. 42, Bureau of Mines, 1914, 116 pp., 2 pls., 23 figs.

A special bulb burette has been constructed, consisting of eight superimposed bulbs, each having a capacity of 100 c. c. A narrow constriction joins each bulb, upon which the graduation mark rests. With this burette any number of 100 c. c. of sample from 100 to 800 can be used for measuring the sample and forcing it through the train. An aspirator bottle on the end of the train assists this displacement.

APPARATUS FOR OTHER ANALYSES.

For the analysis of gas mixtures containing large quantities of CO_2 , CO , CH_4 , etc., the apparatus used contains a burette with a capacity of 100 c. c. and is graduated in tenths of 1 c. c. The burette has the same diameter from top to bottom. Carbon dioxide is removed by caustic potash solution, oxygen by alkaline pyrogallate solution, olefins by fuming sulphuric acid, carbon monoxide by cuprous chloride solution, hydrogen by slow combustion or colloidal palladium, and methane and ethane by slow combustion.

Forms of gas-analysis apparatus have been assembled for special purposes; for example, a portable apparatus for the rapid determination of methane by mine superintendents, inspectors, etc.; a portable apparatus for the approximate analysis of mine gases to determine the composition of the atmosphere in areas that have been sealed because of mine fires; a laboratory form of apparatus for the exact determination of methane by chemists at coal mines, etc.

Hydrogen sulphide is quantitatively determined by means of standard solutions of sodium thiosulphate and iodine.

Palladium chloride or blood solutions are used for the qualitative detection of carbon monoxide.

DETERMINATION OF OXIDES OF NITROGEN.

Experimental work performed by the bureau has shown that Busch and Guthbeier's "nitron" method, used for the quantitative analysis of nitric acid and nitrates, may be used for the determination of small quantities of oxides of nitrogen in mine air.

CHEMICAL CONTROL OF GAS MIXTURES USED AT THE PITTSBURGH STATION.

Natural gas is used at the Pittsburgh station in forming the gas-air mixtures used for testing explosives, safety lamps, electric motors, etc. The natural gas contains about 83 per cent methane, 16 per cent ethane, 0.03 per cent carbon dioxide, and 0.97 per cent nitrogen. Hydrogen, carbon monoxide, and olefin hydrocarbons are absent. A study of the explosibility of the gas indicated that it differed little in that respect from methane, the combustible gas usually found in mines.^a Each mixture as it is prepared at the gallery is

^a Burrell, G. A., The natural gas used at Pittsburgh: Bull. 15, Bureau of Mines, 1912, pp. 66-77.

sampled and sent to the laboratory for analysis. The sample is simply transferred to a gas-analysis apparatus, measured, and burned by the slow-combustion method. The contraction produced by this combustion is measured. When the contraction produced by the burning of 100 c. c. of natural gas is known, it is a simple calculation to compute the amount of natural gas in the gas-air mixture from the contraction in volume it undergoes on burning.

At one of the galleries a thermocouple is used by H. H. Clark, electrical engineer, for determining the percentages of natural gas in the mixtures he uses for testing the safety of electrical apparatus in mines. The readings of this thermocouple were standardized by gas analyses.

OTHER METHODS OF DETECTING GASES.

A gas interferometer has been received by the bureau, and has been fully tested. It gives satisfactory results.

Birds for use in exploring mines are kept at all the mine-safety stations and cars of the bureau. They have been found much more sensitive to carbon-monoxide poisoning than mice.

Paraffin hydrocarbons in a mixture of several are separated from each other by fractional distillation at low temperatures.

MINE-RESCUE BREATHING APPARATUS.

By J. W. PAUL.

APPARATUS UNDER TEST.

The bureau has had under consideration and has conducted tests of the following types of breathing apparatus:

Types of breathing apparatus tested by Bureau of Mines.

Type of apparatus.	Essential agent.	Place of invention.
Vajin Bader.....	Compressed air.....	United States.
National helmet.....	do.....	Do.
Barnum's respirator.....	Fresh air.....	Do.
Merryman's respirator.....	Oxone.....	Do.
Servus.....	do.....	Do.
Hall's emergency.....	do.....	Do.
Pneumatogen II.....	KNaO ₂	Austria.
Aerolith.....	Liquid air.....	Do.
Westfalia (Meco).....	Compressed oxygen.....	Germany.
Draeger.....	do.....	Do.
Fluess (Proto).....	do.....	England.
Koenig.....	Fresh air.....	Germany.
Westfalia.....	do.....	Do.

The tests were made in irrespirable gases (sulphur dioxide, formaldehyde, and smoke from burning straw, excelsior, etc.) in training rooms and in gases following mine explosions and mine fires. The plan of procedure of the tests has been similar to that adopted by the

English Royal Commission as outlined in its first report on breathing apparatus.

The tests made resulted in the purchase for the bureau of a number of the Fluess, Draeger, and Westfalia types of apparatus for use in mine recovery and rescue work, those types being the only ones available that met the requirements and local conditions.

The compressed-air types were found to be unsuited for use in poisonous gases, and the duration of their efficiency with one charge was insufficient for mine work.

The types that generate oxygen by chemical means have so far proved objectionable on account of the slowness with which they liberate the required quantity of oxygen and the high temperature and humidity of the regenerated air. No opportunity has as yet been offered for tests of the latest model of the Pneumatogen apparatus recently ordered.

The liquid-air type has met the laboratory test requirements in so far that it is light and furnishes a cool air and in sufficient quantity, but it has not been adopted for actual mine work because of inability to procure with any degree of regularity a supply of liquid air from the factories, which are far removed from the mining centers. The manufacturers of the apparatus have not installed at any mine in this country an experimental unit for liquid-air production, although it is known that this type has received much favor in some parts of Europe.

During the past two years so much trouble has arisen in the use of the helmet type that its further use is doubtful, the mouth-breathing type proving more desirable.

TESTS.

The gas-tight smoke chamber at the experiment station has been utilized for these tests, in which formaldehyde, sulphur dioxide, and smoke have been used. Repeated tests with different subjects have been made with the various types of apparatus, the tests extending over periods of two hours, during which frequent observations have been made as to the composition of the breathable air, and the pulse, respiration, and physical condition of the subject. With the three types, Draeger, Fluess, and Westfalia, the subjects have had no difficulty in performing their prescribed tasks uninterruptedly until the exhaustion of the supply of oxygen in the bottle.

The individual record of each person trained with the breathing apparatus constitutes a test of the apparatus used. The use of the apparatus in mine-recovery work also constitutes a test of the efficiency of the apparatus, as a record of the behavior of the apparatus and its wearer and analyses of the mine atmosphere obtained are recorded.

TRAINING AND RECORDS.

On the seven mine-safety cars and at the six rescue stations a course of training is prescribed for miners and mine officials who wish to qualify for a certificate. This course covers instruction in the mechanical construction, assembling, charging, and care of the apparatus, and training in its use in mines and in training quarters in the presence of irritating fumes and smoke. Training for two hours each day for six days is required for the completion of the instruction and training for those who are certified by the medical examiner as being in proper physical condition to take the course. In addition to the rescue training the applicant, to obtain a certificate, is required to complete the course in first-aid work.

ACCIDENTS IN USING BREATHING APPARATUS.

Two experienced foreman miners in the employ of the bureau have lost their lives while wearing apparatus within mines. The first death appears to have been due to exposure to poisonous gases immediately prior to putting on the apparatus, and to penetrating then the area filled with the gases from a mine fire. The other death was due to failure of the mechanical construction of the cooler of the apparatus worn, which permitted the gases from a mine fire to enter the circulating system of the apparatus.

LACK OF STANDARDIZATION OF PARTS.

Some difficulty has been experienced from reducing valves failing to deliver the required quantity of oxygen. Upon testing new valves it is found that they furnish varying quantities of oxygen and at varying pressures, showing a lack of standardization at the factory.

At the suggestion of the writer, the Draeger factory (Lubeck) has recently submitted two apparatus, one equipped with double reducing valves which may be operated separately or in unison, and a second equipped with a by-pass valve for emergency use.

EQUIPMENT OF THE BUREAU AND ELSEWHERE.

The following constitute the breathing-apparatus equipment of the bureau:

Draeger, 1904-7 type.....	18
Draeger, 1910 type.....	47
Draeger, 1911 type.....	16
Draeger, ½-hour type.....	3
Westfalia.....	36
Fluess (Proto).....	8
Aerolith.....	5
Pneumatogen II ^a	1
Koenig Fresh Air.....	1
Westfalia Fresh Air.....	4
Hall's Emergency.....	30
Total.....	169

^a Model III ordered.

There are now installed at mines in the United States about 1,000 breathing apparatus, principally of the Draeger, Fluess, and Westfalia types.

Private rescue-training stations have been equipped for training and emergency work in several of the States, and seven railroad cars for such work have been put in service by different mining companies, and three by the State of Illinois.

The schedule of training that the bureau uses, together with the form for reporting the work accomplished by the person who may wear the apparatus, and the physician's examination card are described in publications of the bureau.^a

The extent to which persons trained should be tested to ascertain the cumulative physiological effects of artificial breathing so far as the tests will determine the adaptability of certain persons for rescue service is a matter upon which the advice of this conference should be beneficial.

The advisability of training with compressed air in the oxygen bottle and discharging the exhaled air to the atmosphere to avoid the expense of upkeep for oxygen and regeneration is also suggested as a subject for discussion and advice.

MINERS' SAFETY LAMPS.

By J. W. PAUL.

LAMP TESTS CONDUCTED BY BUREAU.

The schedule of tests of miners' safety lamps (those burning oil, naphtha, and acetylene) has for its purpose the determination of the following details:

1. The liability of the flame of the lamp to ignite explosive mixtures of air and gas under velocities of 200 to 3,000 feet per minute in horizontal currents and in ascending and descending and vertical and oblique currents.
2. The liability of the flame to ignite external mixtures of gas and air when subjected to sudden concussion.
3. The effect of small percentages of explosive gas upon the flame of the lamp and the effect of inert gases when present with explosive gas.
4. The liability of various types of internal igniters to fire gas outside of the gauzes of the lamps.

^a Paul, J. W., The use and care of mine rescue apparatus, Miners' Circular 4, Bureau of Mines, 1911, 24 pp.; Training with mine-rescue breathing apparatus, Technical Paper 29, Bureau of Mines, 1912, 16 pp.

5. The effect of the heat of the lamp flame on glass chimneys, and the effect of impact on the frame and the glass chimney.
6. The candlepower of the lamp and length of time it will burn.
7. The mechanical construction and stability of the lamp.

The lamps are subjected to the following tests:

1. A lamp being tested is placed in mixtures of air and explosive natural gas having 6, 8, and 10 per cent of gas, moving at a velocity of 200 to 3,000 feet per minute, to determine the velocity at which the lamp may ignite the mixture surrounding the lamp. The current is made to move against the lamp in a horizontal direction and while ascending and descending vertically and obliquely.

2. Upon the completion of the series of tests as here outlined, the lamps are given tests similar to those outlined in the preceding paragraph with the mixture of air and gas under pressure.

3. Under the conditions outlined in 1, coal dust is introduced into the current of air and gas to determine its effect, if any, upon assisting the ignition of the external mixture of gas and air.

4. The lamps are placed in a mixture of air and varying percentages of explosive natural gas to determine the action of the gas on the flame of the lamp.

5. The lamp is placed in a mixture of air and explosive gas and varying percentages of carbon-dioxide gas to determine the action of the gas mixture on the flame of the lamp.

6. Lamps equipped with internal igniters are placed in explosive mixtures of air and gas in a quiet state and in a moving current and the effect on the mixture surrounding the lamp of operating the igniter is observed.

7. The oils (illuminants) used within the lamps are tested as to their viscosity, gravity, flash point, congealing point, and composition.

8. A safety-lamp globe is tested by placing the globe in position in the lamp and allowing the flame of the lamp to impinge against the globe for a period of 5 minutes after the lamp has been burning with a full flame for 10 minutes, to determine whether the globe will break.

9. A safety-lamp globe is mounted within a lighted lamp with upfeed and placed for 5 minutes in an explosive mixture of air and gas moving at 1,000 feet per minute, to determine whether the heat will break the glass, and to note the character of the fracture.

10. A safety-lamp globe is broken by impact, by allowing the globe to fall by gravity upon a block of seasoned white oak, the distance the globe falls being recorded.

11. A safety-lamp globe is mounted within a safety lamp and when in a horizontal position a steel pick of 100 grams weight is permitted to fall a sufficient distance to break the globe.

12. To determine the candlepower of a safety lamp, a photometer equipped with a standardized lamp is used. The candlepower is determined along a line at right angles to the axis of the flame, also at angles to the axis of the flame, both above and below the horizontal. The candlepower is read at frequent intervals during the time the flame burns with a full charge of fuel.

13. The time a safety lamp will continue to burn with a full charge of illuminant is determined.

14. The wick of a lamp is of sufficient length always to be in contact with the bottom of the vessel in which the illuminant is contained and before being used the wick is dried to remove moisture.

15. To test the stability of the lamp, it is permitted to fall by gravity from different heights, and the lamp is suspended and subjected to sudden violence by dropping known weights attached by cable to the lamp.

APPARATUS USED IN TESTING.

For tests in moving currents of gas and air a horizontal steel gallery 6 inches wide, 12 inches high, and 20 feet long, having a vertical and two 45-degree compartments, is used. This is similar in detail to the galleries used at Frameries, Belgium, and at Gelsenkirchen, Germany. At the exhaust or outlet end is a steam ejector which may be used for aspiration, and at the intake end is a blowing fan, 10 inches by 24 inches, which may be used for driving the air through at a pressure slightly above atmospheric. The calibration of the gallery was much simplified by the use of the fan, to the exclusion of the ejector. A "Schorndorff" apparatus will be attached to the gallery for igniter tests.

The apparatus for testing under concussion is similar to that used at the University of Leeds, England, and consists of a 3-inch pipe, 15 feet long, having a diaphragm at a central point and a perforated coil into which the lamp is placed for testing.

For testing for flame caps a gallery 8 feet long, 24 inches high, and 8 inches wide, equipped with diaphragms for mixing gas and air, and a fan for a slow movement of the mixture is installed. This is similar in construction to the gallery used for the same purpose at the Birmingham University, Birmingham, England, though the method of operation is different.

Tests of igniters are made in a moving current of gas and air in lamp gallery 1, and in still atmosphere in gallery 3, which is a steel box 24 by 18 by 18 inches.

In the heat test of lamp chimneys the flame of the lamp is permitted to impinge on a chimney for five minutes; if the chimney is broken, the nature of the fracture is determined.

In the impact test the chimney is permitted to fall on a block of wood; also a small anvil weighing 100 grams is allowed to fall on the chimney, the height of fall required to break the chimney, and the character of the break being noted.

The candlepower of the lamps is determined by the use of a Leeds & Northrup precision photometer of the "Reichsanstalt" pattern, using the Lummer-Brodhem comparison screen. The standard of comparison is a Mazda tungsten lamp of 2 candlepower at 10 volts and 0.227 ampere, standardized by the United States Bureau of Standards.

LAMPS TESTED.

The following types of lamps have been procured and subjected to preliminary and official tests:

Type.	Where manufactured.	Type.	Where manufactured.
Wolf.....	Germany.	Davy.....	United States.
Seippel (bonneted).....	Do.	Clanny (bonneted).....	Do.
Seippel (unbonneted).....	Do.	Clanny (unbonneted).....	Do.
Schenk.....	Do.	Mueseler.....	Do.
Pieler.....	Do.	American naphtha.....	Do.
Ackroyd & Best.....	England.	Routledge-Johnson.....	England.
Davis.....	Do.	Thomas.....	Do.
Clowes.....	Do.	Beard Deputy.....	United States.
Stokes.....	Do.	Naylor.....	England.
Ashworth-Hepple-White- Gray.....	Do.	Marsaut.....	Do.
Szombathy.....	Austria.	Chesneau.....	France.

LEGISLATION RELATING TO SAFETY LAMPS.

The State of Pennsylvania is the first and only State to adopt a list of permissible safety lamps. Legislation of 1912 requires that all types of safety lamps used in the bituminous mines of the State shall have the approval of the State department of mines. The tests made by this bureau have been accepted by the department of mines of Pennsylvania, and the following types of bonneted safety lamps have been approved by the State mining department for general use in the bituminous mines of Pennsylvania if the velocity of the ventilation current ranges from 600 to 1,500 feet per minute: Clanny, Davis Deputy, Wolf, Schenk (new type), Seippel, and Ackroyd & Best.

The tests of igniters is in an experimental stage. Only within recent months have cerium alloy igniters made their appearance in America. The igniters generally in use are of the tape design. Some percussion igniters were introduced about two years ago, but because of their disrepute in Europe they were withdrawn upon advice from this bureau.

PROPOSED TESTS.

The influence of coal dust in the presence of moving currents of mixed gas and air in aiding the passage of flame through the gauze of a safety lamp provided therewith and the action of the flame of a safety lamp in the presence of methane, carbon dioxide, and air will be investigated in future tests.

The relative safety of lamps when tested in mixtures of gas and air under different velocities and above the normal atmospheric pressure will be determined. As yet no results of any such tests that may have been made in Europe have been received.

INVESTIGATION OF EXPLOSION-PROOF ELECTRICAL EQUIPMENT.

By H. H. CLARK.

Several months ago the bureau completed an investigation of several explosion-proof motors.

Five motors were investigated, but the protection of two of them was too crude to be of interest. Of the three that operated well, one was protected by three layers of gauze covered by a poppet valve. Another was protected by several layers of gauze laid between heavy plates of perforated metal and inclosed in a bronze housing with a baffle-plate discharge opening. The third motor was protected by plates arranged after the German practice. This machine was built after the designs of the Allgemeine Electricität Gesellschaft.

All of the protective devices were vulnerable. The type embracing gauze and a poppet valve seemed to work fairly well, although it allowed flames to be discharged through the relief openings. However, ignition rarely occurred unless both poppet valves were open when the gas within the motor casing was ignited. With the poppet valves open, puncture^b usually occurred. The motor that was protected by poppet valves was equipped with two of these devices. If one valve was fastened shut and the other left open, puncture was not likely to occur. Thus the conclusion was reached that the trouble was due to the low pressure maintained by the explosion when it was initiated with both valves open. The temperature of the discharged gases was no doubt affected by the way in which they expanded upon leaving the lip of the poppet valves, and this expan-

^a See Clark, H. H., An investigation of explosion-proof mine motors: Bull. 46, Bureau of Mines, 1912, 44 pp., 6 pls., 14 figs.

^b The term puncture refers to the ignition of gas surrounding the motor by flames issuing from the motor casing.

sion depended upon the pressure generated within the motor casing by the explosion.

The device that used sheets of gauze laid between metal plates worked perfectly with gas alone, but punctured when coal dust was present just outside of the outer plate. My hypothesis of this is as follows: The gauzes chilled the discharged gases that passed through them first and these gases filled with noncombustible material the space just outside the gauzes, so that when the later flames emerged through the gauzes there was nothing to ignite and propagate the flame. When dust is present, however, it is thrown up in a cloud by the first blast of the explosion, and the later flames raise the dust to its ignition temperature, although, on account of deficiency of oxygen, it can not burst into flame until it reaches the outside air, where the dust takes fire and ignites the gas surrounding it. In support of this hypothesis, when puncture occurs no flames are seen to issue from the discharge openings, but the explosion seems to initiate from a point several inches outside them.

The plate protection was adequate as long as the motor was at rest, but when the motor was running the fan that was attached to the armature shaft refilled the motor casing with gas and caused a series of explosions that eventually heated the plates, so that they no longer prevented the passage of flames, which finally shot out 6 or 8 inches beyond the discharge openings and ignited the gas surrounding the motor.

I shall be glad to hear a discussion as to the best form of protective device and as to a suggested specification for covering "permissible motors"; also as to whether such a motor should be permitted to discharge flames even though no puncture occurs; as to how many trials should be made; as to how we should regard a motor that, when running, permits the occurrence of several successive explosions within the motor casing; and as to whether a motor should be considered unless satisfactory flame-proof starting devices are supplied and tested with it.

IGNITION OF GAS BY STATIONARY INCANDESCENT LAMPS.^a

By H. H. CLARK.

The bureau has just completed an extensive investigation of such incandescent lamps as are used for general illumination in mines.

About 1,200 lamps were tested. They varied in voltage from 50 to 225 and in candlepower from 8 to 50. Most of them had carbon filaments.

^a See Clark, H. H., and Hsley, L. C., Ignition of mine gases by the filaments of incandescent electric lamps: Bull. 52, Bureau of Mines, 1913, 31 pp., 6 pls., 2 figs.; also Clark, H. H., Ignition of mine gas by miniature electric lamps: Technical Paper 23, Bureau of Mines, 1912, 5 pp.

The tests were made by smashing the lamps, by breaking off the tips, and by punching a hole in the necks of the lamps. Tests were also made with the naked filaments.

The favorable results obtained with such lamps as did not ignite the gas were confirmed by increasing the impressed voltage until ignition was produced when the lamp was smashed.

The results of the tests showed that all the classes of lamps tested will ignite gas under certain conditions, although some lamps are less likely than others to cause ignition. The lamps most used in the mines of this country (16 candlepower, 110-volt) gave five ignitions out of 62 trials in the smash test and three ignitions out of 23 trials in the tip-breaking test. The over-energy test also showed this lamp to be close to the danger line.

There are two points that I would be glad to have discussed—one is the most efficient means for protecting lamps from breakage after they are in place underground, and the other is the ultimate cause of the gas ignition.

In 58 tests in which the gas was ignited, the filaments continued to glow from 2 to 59 seconds after ignition had taken place, indicating that glowing filaments may ignite gas.

Fifty tests made upon 50, 60, and 120 watt, 110-volt lamps showed a greater percentage of ignitions when the lamps were connected in multiple than when they were connected in series, although the breaking spark was drawn at 110 volts in the former tests as against 550 volts in the latter. This result seems to show that the unassisted spark can not ignite gas.

By breaking a noninductive, 550-volt circuit between a steel contact and a carbon contact, it was found that when the current exceeded 0.15 ampere an ignition was always obtained when the circuit was opened. Yet 10 tests made with five 110-volt lamps connected in series across 550 volts produced no ignition, although the filament of the tested lamp carried one-half an ampere, and the spark must have been drawn at 550 volts. Neither were ignitions obtained from 11 similar tests made with lamps carrying approximately 1 ampere.

I believe that the spark that is drawn when a lamp filament is broken is to a great extent "blown out" by the entering current of gas. To prove this point, a 50-watt, 55-volt naked filament was connected in series with noninductive resistance, and 0.5 ampere (one-half normal current) at 110 volts was passed through the circuit. The filament was then broken by gradual pressure which distorted it until it snapped off. Five ignitions were obtained from six tests made in this way. Similar lamps were then connected in series with noninductive resistance across 550 volts, and the filaments were disrupted by smashing the lamp bulbs. Five tests were made,

three at 0.6 ampere and two at 0.7 ampere. No ignition was obtained in any of the five trials, although the current was 20 to 40 per cent greater and the voltage 400 per cent greater than in the five tests that gave ignitions with the naked filaments. It is therefore manifest that the inrushing gas has a quenching effect upon the spark.

Five tests were then made by connecting a 175-watt, 55-volt lamp (normal current 3.5 amperes) in series with a noninductive resistance of such value that 2.25 amperes flowed through the filament when 550 volts was impressed across the lamps and resistance. The lamp was surrounded with gas and smashed while carrying this current. No ignition resulted from five trials, although the current broken was somewhat greater and the voltage ten times greater than in the tests of lamps that invariably produced ignition when broken while burning under normal conditions.

It is manifest that the spark alone did not cause these ignitions, if ignition could not be caused by a similar spark with ten times the voltage behind it.

I am inclined to believe that the likelihood of gas ignition by the standard carbon filament is directly proportional to the cross section of the filaments. The filaments of 24 different types of standard lamps were measured by Reinhardt Thiessen, assistant chemist, and the cross sections of the filaments were compared with their tendency to ignite gas as expressed in percentage of ignitions obtained in a given number of trials. All filaments having a cross section of 0.000177 square centimeter, or less, failed to ignite gas when the lamps were smashed. All filaments having a cross section of 0.000234 square centimeter, or more, invariably ignited gas under the same conditions, whereas filaments having a cross section of 0.000194 square centimeter ignited gas in 50 per cent of the trials, and filaments having a cross section of 0.000215 square centimeter ignited gas in 83 per cent of the trials. It is true that a similar relation existed between the current flowing in the filaments and the percentage of ignitions that they gave, but I do not regard this relation as significant, because I believe that the spark that is drawn when a filament is broken is not responsible for the ignition of gas.

If the bulb of a glowing incandescent lamp is smashed while surrounded by an explosive mixture, and if the filament is not broken by the jar of the blow, the filament is first cooled by the inrushing gas and then broken by it. Of course, the cooling and the breaking are almost simultaneous, but I believe that ignition, if it occurs, takes place during the period of cooling and before the filament is broken.

If this hypothesis is correct, there are two reasons why large filaments ignite gas more readily than smaller ones. First, the temperature of the larger filaments is not reduced so greatly before they are broken, and, second, the larger filaments do not succumb so quickly to the breaking action of the inrushing gas.

PORTABLE ELECTRIC LAMPS FOR MINE SERVICE.^a

By H. H. CLARK.

The bureau is now preparing to conduct an investigation of portable electric lamps for use in mines. Besides dry-battery flash lamps there are now on the market at least half a dozen American portable electric lamps.

The bureau feels that the introduction of the electric lamp will increase safety in mines whether gaseous or not, and hopes to stimulate interest in the manufacture and use of such lamps by thoroughly investigating as many as can be obtained, for the purpose of making a report that shall deal with the efficiency and cost of maintaining the lamps as well as with their liability to ignite gas accidentally.

Of the six kinds of American lamps immediately available, two are of the self-contained type, the lamp and the battery being mounted together; two are of the separate type, the lamp being mounted separately from the battery and connected to it by flexible conductors; and each of two others is designed to be used either as a self-contained lamp or with the lamp separate from the battery.

The self-contained types are, with one exception, designed to be carried in the hand. The design and construction of the exception noted contemplate the wearing of both lamp and battery upon the miner's cap.

The bureau has already tested over 100 such lamp bulbs as would be used in portable lamps and the results show that ignition of gas will be caused by any such bulb that gives about 1 candlepower or more, if the bulb is broken so that the filament remains intact. The bureau has also made a few preliminary tests with sparks from non-inductive circuits. The results so far obtained show that such sparks as would be given from a portable electric lamp will scarcely ignite gas. The principal source of danger from portable lamps is, therefore, the breaking of the bulb so that the filament is intact.

In the bureau's future investigation each lamp will be examined as to its ability to ignite gas and the candlepower, the life of the lamp bulbs and the number of hours that the batteries will operate their respective lamps on one charge or filling will be ascertained. Also, the care and manipulation incident to the use and maintenance of the lamps, the convenience and adaptability of the various lamps to the purposes of mining, and the cost of maintenance and repairs will be compared. As a result of this investigation the bureau will be able to draw specifications for lamps suited for underground service

^a Clark, H. H., Permissible electric lamps for miners: Tech. Paper 75, Bureau of Mines, 1914, 21 pp., 3 figs.

These specifications should be of help to the manufacturer as well as to the consumer.

Personally, I would be glad to see a standardized test or a specification for examining or measuring the safety of a lamp that uses a bulb that ignites gas when the bulb is broken. I believe that we shall find that all lamps of any appreciable light-giving power must use bulbs of this sort, and therefore the method of protecting the bulbs from injury becomes the paramount issue. The measure of danger is the likelihood of so breaking the bulb that the filament will not be injured. The measure of safety is the converse, and if a lamp is to be pronounced safe the proof that its bulb can not be broken without destroying the filament must be established. In the test under consideration it is almost impossible to select conditions that will be fair to both sides, and so I believe it to be inadvisable to attempt to determine by test either the absolute or the relative safety of the lamps if a reasonable number of tests do not give positive results.

At present it seems to me that the best solution is to require for gaseous mines a bulb mounting so designed that a blow sufficient to break the bulb will automatically open the lamp circuit. In presenting the standardization there are other details with which we should like your assistance, such as fixing the minimum candlepower, the minimum length of burning on one charge, the most desirable distribution of light, the minimum length of life of the lamp bulbs, and a test for determining the ruggedness of the equipment.

DANGEROUS ELECTRICAL EQUIPMENT AND METHODS OF SAFEGUARDING IT.^a

By H. H. CLARK.

It is the purpose of this paper to start a discussion as to what parts of underground electrical equipment are most dangerous to the miner and how the danger may be lessened, and to bring out recommendations for improving the standard of safety of electrical equipment in mines.

As far as can be determined from official reports, most of the electrical accidents in the mines of the United States are electric shocks, and the major part of these are caused by the trolley wire, which I consider to be the most dangerous part of the electrical equipment of our mines. Some shocks are also received from the trailing cables,

^a See Clark, H. H., The factor of safety in mine electrical installation, Technical Paper 19, Bureau of Mines, 1912, 14 pp.

service lines, and frames of coal-cutting motors and from the accidental charging of apparatus that is not supposed to carry current.

It is rare that an explosion or a disastrous fire is reported as being caused by the electrical equipment.

In this country, as you probably know, direct current is used almost altogether for underground distribution and much bare wire is used not only for trolley service but also for carrying power to coal-cutting and pump motors. One side of the direct current distributing system is almost invariably grounded in order to use the earth as a return conductor.

It impresses me that the solution of the problem of reducing electrical dangers in coal mines embraces the following details: First, in forbidding the use of electricity in places where fire damp is regularly found in more than the most trifling amounts; second, in using flame-proof apparatus wherever outbursts of gas are likely to be encountered; third, in selecting underground electrical equipment with reference to the service that it must endure, choosing motors that are well insulated, switches that are durable, and other equipment capable of resisting rough handling and moisture; fourth, in properly installing equipment; fifth, in properly caring for and maintaining equipment.

The solution, as far as the operator is concerned, can be expressed in four words—good apparatus, good electricians—and the electricians are to my mind the first consideration. Good electricians mean the selection of good apparatus and the proper installation and maintenance of it. Thus are obtained three of the five essentials of safety as regards the use of electricity. For the remaining two essentials we must rely upon the State inspection departments, which are made up of men admirably equipped with the necessary experience and judgment and provided with full and unhampered authority over the matters at issue.

Does not our analysis therefore disclose the electrician as the important factor in the problem of safeguarding the use of electricity in mining? Of course lack of cooperation on the part of the mine management may so hamper the most competent of electricians that his efforts may be unavailing, but nevertheless the electrician holds the key to the situation.

My idea of a good electrician is, first of all, a good workman, a man who can do good work himself and who therefore can tell when work is well done. He should have a great deal of mechanical skill as well as experience with electrical machinery. He should believe in doing his work well, not merely well enough. His experience should not stop with the knowledge of making a simple splice or even with the ability to improve the commutation of a sparking motor. He should have an active mind, ready to grasp the lessons to be learned from his ever-varying experiences, and above all he should have the desire

to acquire knowledge and improve the character of his work. Such a man, dealing with the problems at the closest range and in position of greatest advantage, has the power to safeguard truly and effectively the use of electricity in mines.

NOTES ON HOISTING ROPES.

By O. P. HOOD.

The American habit of depending on the manufacturer of a product for engineering advice regarding the quality and use of that product is well exemplified in the current practice regarding hoisting ropes. The usual buyer follows the recommendation of the ropemaker as to the kind and quality of rope best suited to his needs, and is inclined to hold the maker responsible for a reasonable length of life for the rope and for its safe and adequate service. The ropemaker assumes this responsibility, even to the extent of submitting to a money forfeit, to retain the patronage of large customers who may have been dissatisfied with the performance of a particular rope. Some buyers believe that this policy of throwing the responsibility for adequate service entirely on the ropemaker is to be preferred to any method whereby the purchaser prepares a more detailed specification of quality and properties, expressed in the technical phrases of the subject of materials. It appears, however, that ropemakers are sometimes unable to furnish a product that gives a uniform service under identical conditions, or that the user is unable to recognize that conditions are not identical with successive ropes. The tensile strength of the rope as shown by a testing machine, and the tests of individual wires as to strength, ductility, and resistance to repeated bending, are factors not readily translated into the length of service of a construction so complicated as that of a rope. The purchaser may receive with the rope a record of its tensile strength, which usually agrees closely with the maker's catalogue claims, but of which he makes practically no use in determining the life and usefulness of the rope. The development of a method of testing ropes that shall more nearly approximate the working conditions of the rope is desired, and, when this is available, it will aid in interpreting the simpler tests now in use. The present method of condemning a hoisting rope is entirely a matter of judgment and lacks a rational basis.

It is rare to find a man intrusted with the care of hoisting ropes who can give such directions for condemning a rope that others can safely follow his directions, and although the general tendency of

inspectors is probably to err on the side of safety, still an occasional unfortunate judgment leads to disaster.

Some more certain method is needed than visual inspection and the judgment of one man more or less skilled.

Inspectors in the same general field, in forming their judgment of the condition of a rope, place varying weight on such factors as length of service, regardless of the appearance of the rope; the tonnage lifted, regardless of the time of service; the ton-miles of service of the rope; the number of visible broken wires in some definite length of strand or rope; the reduction of diameter; the amount of stretch; the decreasing strength as shown by tensile tests of pieces removed from the end near the skip; an estimate of reduction of area due to wear; corrosion and lack of lubrication; and a bending test of individual wires removed from the rope near the skip end. No one inspector is keeping all these data. In practical rope inspection, is it possible with present knowledge to formulate a standard method that shall give proper weight to these several factors?

It seems as though it might be possible to record autographically the changing pitch of the twist of a rope while in use, a change that would show the relative extension of each section of the rope during use and thus call attention to an overloaded section.

BASIS FOR TESTS OF GASOLINE LOCOMOTIVES.

By O. P. HOOD.

It is known that the gasoline locomotive may be so used in mines as to endanger the lives of miners and operators by the emission of carbon monoxide. In determining the conditions under which such locomotives may be used, it is necessary to consider the engine as a carbon monoxide generator and discover the conditions under which this production is at a maximum. This maximum is the result of several variable conditions. It is suggested that it be assumed that the operator at the mine will stop his machine only as a result of two easily observed conditions, as follows: (1) The slowing down of the engine to one-half or two-thirds normal speed, as shown by a decided change in the sound of the running parts when running without load, and (2) the inability of the locomotive to pull more than one-half the normal load at any speed. Until the locomotive reaches these two limitations, it can be assumed that the machine may be run in a mine. Bad conditions can be produced by over-carburization due to bad carburetor adjustment and by other variable factors, and so long as

the carburetor adjustment is in the control of the operator, bad conditions must be assumed as possible within the mine. Such conditions as bad carburization, misfiring, cracked cylinders, excessive lubrication, lack of compression, etc., as shall be found to give only one-half the normal power and shall at the same time give a maximum of carbon monoxide, must be considered as possible in the mine and as determining the gas output of the device. Under what conditions of ventilation this quantity of noxious gas may be tolerated so as to bring the percentage of carbon monoxide below 0.1 per cent, a limit suggested by Mr. Burrell, chemist, of the Bureau of Mines, can then be determined.

THE ANALYSIS OF EXPLOSIVES.

By C. G. STORM.

PERMISSIBLE EXPLOSIVES.

The "permissible" explosives employed in the United States for use in coal mines may, from the standpoint of chemical examination, be grouped as follows: (1) Modified nitroglycerin dynamites, (2) ammonium nitrate explosives, (3) nitrostarch explosives. A fourth group of chlorate explosives may properly be added, but it is to be noted that as yet no chlorate explosives have passed the tests for permissibility.

In the first group the necessary reduction of temperature is produced by one or more of the following means:

1. The addition of an excess of carbonaceous material in quantity sufficient to largely reduce the amount of carbon dioxide evolved on explosion. Wood pulp, wheat flour, and corn meal are the most commonly employed materials of this type.

2. The addition of free water. Amounts as high as 12 per cent have been successfully used.

3. The addition of salts containing water of crystallization; for example, alum, magnesium sulphate, aluminum sulphate, or gypsum, in quantities from a few per cent to as much as 35 per cent.

4. The addition of volatile salts, such as sodium chloride or ammonium salts, in proportions up to 20 per cent.

5. The addition of inert substances, such as clay, sand, powdered slate, or kieselguhr (infusorial earth).

In most of the ammonium nitrate group of explosives there is some nitroglycerin or nitrotoluenes or both, together with some carbonaceous material. These additions to the ammonium nitrate materially raise the low explosion temperature of the latter, so that

some of the means mentioned above must be employed for reducing the temperature. Thus, we have ammonium nitrate explosives containing sodium chloride, ammonium sulphate, or some other volatile salt, or containing some salt holding water of crystallization.

The nitrostarch explosives depend for low temperature upon either a proper proportioning of nitrostarch, sodium, and ammonium nitrates, and carbonaceous matter, or on the addition of large proportions of inert nonvolatile substances; for example, as much as 45 per cent of calcium carbonate.

METHODS OF ANALYZING EXPLOSIVES.

With such a variety of means for reducing the temperature of explosion, it is apparent that the method of analysis employed must in each case be specially adapted to the particular explosive under examination. The general scheme of analysis employed in the explosives chemical laboratory of the Bureau of Mines depends on a separation of the ingredients of the explosive into groups according to their solubility, followed by the separation or determination of each group constituent by some appropriate method. Thus, in the great majority of analyses, the explosive is extracted with ether, then with water, and finally with dilute hydrochloric acid. The ether removes completely nitroglycerin, nitrosubstitution compounds, oily materials, resins, etc., the water dissolves the nitrates and other water-soluble salts, and the acid removes the calcium or magnesium carbonate or other water-insoluble antacid substances. The residue left after each extraction is dried and weighed, the loss of weight indicating the total weight of extracted material.

The components of the final insoluble residue are generally recognized by microscopic examination. Starch, if present, is determined by acid hydrolysis. The insoluble residue is finally ignited and an examination made of any mineral residue other than the natural ash of the wood pulp, etc. Each component of the different extracts is then determined, a complete qualitative examination having previously indicated the substances in each solution.

The above general outline of a method of separation will, of course, not apply in all cases. For example, the presence of nitrocellulose, nitrostarch, or sulphur necessitates the use of additional solvents.

Moisture in the explosive is determined by desiccating a sample of 2 or 3 grams over concentrated sulphuric acid, the sample being spread uniformly over the surface of a 3-inch watch glass. In general, the loss of weight after three days' desiccation is regarded as moisture, experiments having shown that there is a continual loss of nitroglycerin during desiccation, this loss being a function of the temperature and duration of desiccation. A sample of ordinary nitroglycerin dynamite containing approximately 1 per cent moisture has shown a gradual loss on desiccation over sulphuric acid at a con-

stant temperature of 33° C. for a period of 183 days, the total loss at that time being 7.55 per cent.

When salts containing water of crystallization are present, this method does not of course give even approximate results, and as from most of such explosives it is impossible to determine separately the moisture and the water of crystallization or even to completely remove the total water present without some alteration of other constituents, the moisture is determined by difference; that is, the sum of all constituents directly determined is deducted from 100 per cent and the difference assumed to be the moisture content. This method is unsatisfactory, as any accumulated errors in all other determinations are thrown on the moisture determination.

Among other details deserving special note in this brief outline may be mentioned the determination of mixtures of nitroglycerin and nitrosubstitution products in the ether extract. Experiments have shown that in mixtures of nitroglycerin and dinitrotoluenes or trinitrotoluenes, the nitroglycerin can be accurately determined by means of the Lunge nitrometer, but that the presence of mononitrotoluene introduces serious errors. The monocompound is quantitatively converted in the nitrometer to the dicompound by the nitric acid liberated from the nitroglycerin during the reaction, thus giving a low result for the determination of the nitroglycerin. To be exact, 1 gram of mononitrotoluene takes up completely the nitrogen from 0.5530 gram of nitroglycerin. The experiments mentioned have not as yet been extended to nitrocompounds other than the nitrotoluenes.

Other researches have shown that an approximate separation of nitroglycerin from nitrosubstitution compounds is possible by the use of a combination solvent, as dilute acetic acid (65 per cent) and carbon bisulphide. These two solvents do not mix, but the nitroglycerin is almost completely absorbed by the acetic acid, and a fairly definite proportion of the nitrosubstitution compound is recovered from the carbon bisulphide. This definite fraction is previously determined by experiments on known mixtures. When properly performed the process gives fairly accurate results.^a

In the analysis of some chlorate explosives it has been found necessary to determine a nitrate and chlorate in the same aqueous solution. The determination was satisfactorily effected by reducing the chlorate to chloride by passing a current of SO₂, heating to expel most of the excess SO₂, and oxidizing the remainder with hydrogen peroxide solution, determining the chloride as silver chloride in one part of the solution and the nitrate gravimetrically in another part by means of the "nitron" method of Bush.

^a Improvements in this method are described in a paper by A. L. Hyde—The quantitative separation of nitrosubstitution compounds from nitroglycerin: Jour. Amer. Chem. Soc., vol. 35, 1913, pp. 1173-1182.

DETONATORS AND ELECTRIC DETONATORS.

The detonating composition generally employed in the United States consists of a mixture of approximately 90 per cent mercury fulminate and 10 per cent KClO_3 . Electric detonators contain a priming charge of either the same composition as the main charge or of fulminate alone, or of long-fiber guncotton. The priming charge is placed loosely on top of the compressed charge and surrounds the bridge wire.

Such a composition is analyzed by completely transferring the dry charge to a filtering crucible, moistening it with alcohol to thoroughly wet it, and extracting the chlorate with water. The small amount of fulminate dissolved by the water is determined as HgS by precipitation with H_2S , and in the filtrate from the HgS the KClO_3 may be determined directly by double evaporation with nitric and sulphuric acids, weighing as K_2SO_4 the final residue after ignition.

No trinitrotoluene detonators are as yet manufactured in this country.

PRODUCTS OF COMBUSTION OF EXPLOSIVES.

The products resulting from explosion are determined by collecting the gases, solids, and liquids from the Bichel gage after 200 grams of the explosive in its original wrapper has been fired. The gage is evacuated before the firing, and electric ignition is used. One-half hour is allowed for the products to cool before they are collected.

The gases are sampled by collecting over mercury a differential sample representing practically the entire gas volume, and the solid and liquid residues are removed as completely as possible from the gage.

The analysis of the gas sample is made with the Hempel apparatus by the usual methods. For ordinary purposes, no correction is made for the gases resulting from the electric detonator, as their volumes would be practically negligible in comparison with the volume of gases from 200 grams of explosive. No attempt is made to obtain more than a qualitative analysis of the solid products because of the fact that they are largely contaminated by iron and copper salts resulting from the detonator legs, the shell, and the wire tripod upon which the cartridge is placed. Owing to the difficulty of collection, only about 95 per cent of the total products of explosion are recovered, the loss being largely solids and liquid.

No attempt has been made in this brief presentation of methods to even enumerate all of the many special details of interest, including the numerous difficulties arising in analysis.

REQUIREMENTS AND TESTS FOR EXPLOSIVES USED IN MINES AND QUARRIES.^a

By CLARENCE HALL.

COAL-MINING EXPLOSIVES.

The methods followed at all stations that are testing coal-mining explosives were devised in order to classify explosives in regard to their suitability for use in coal mines. The testing galleries vary in size, form, and material. The cross section of some of the galleries is elliptical; that of others is circular. At all stations, except in Austria, steel cannons are used at the galleries for firing charges of explosives, the bore of the cannon varying from 40 to 55 mm.

Natural gas is used at some stations and artificial substitutes at others. Most of the Continental stations use coal dust. Either because of differences in the retardation of ignition of the gas mixtures, or because of other conditions at the different galleries, the limit charge established for a given explosive is by no means the same at different stations. In some cases there is even a marked dissimilarity of results.

The use of stemming at foreign stations and at the Pittsburgh testing station has been found to raise the limit charge considerably, especially of explosives of the ammonium nitrate class.

Air spacing inside the bore of the cannon, as practiced at most of the Continental stations, is said to extend the apparent border line of safety. However, it may be stated that the results obtained with different charging densities at the Pittsburgh testing station do not indicate that the border line of safety is necessarily extended with low charging densities; on the other hand some explosives have passed a limit charge of 680 grams when loaded with the charging density of a charge that would not pass with this amount when loaded air spaced.

Many of the ammonium nitrate explosives give low limit charges when tested by the suspended test as practiced in Austria, probably for the reason that as the explosive is not confined the flame temperature is more prolonged.

It has been shown by some of the German stations that many "permitted" explosives are less safe when tested with coal dust alone. It may be mentioned that coal-dust tests were subsequently repeated at other stations, but the results obtained at the German stations were not always reproduced, especially at the stations using pure arti-

^a See Hall, Clarence, and Howell, S. P., The selection of explosives used in engineering and mining operations: Bull. 48, Bureau of Mines, 1913, 50 pp., 3 pls., 7 figs.; Tests of permissible explosives: Bull. 66, Bureau of Mines, 1913, 313 pp., 1 pl., 6 figs.

ficial or natural gas. This may be explained, perhaps, by the fact that the pit gases used at many of the stations are not of uniform composition and contain more or less inert gases.

There is sometimes a small percentage of carbon dioxide and other inert gases present in the pit gases used abroad, the percentage depending on the efficiency and condition of the scrubbers at the time the gases are drawn through. Assuming that the percentage of these inert gases is kept within low limits, there may be at times sufficient inert gases present to have a retarding effect on the ignition. Tests made at the Pittsburgh testing station indicate that a mixture of gas and air containing 8.1 per cent of methane and ethane, 14.2 per cent of carbon dioxide, and 77.7 per cent of air is practically non-explosive when ignition is attempted with an electric igniter containing 5 grains of black powder. It has also been found that the ignition of gas mixtures is materially retarded with a carbon dioxide content of 11.7 per cent, and even when ignited the mixtures burned at a slow rate, accompanied with little if any explosion. For this reason it would be fair to assume that a gas mixture containing a small percentage of carbon dioxide or other inert gases is proportionally less sensitive than a pure gas mixture.

APPARATUS AND METHODS USED AT THE PITTSBURGH TESTING STATION.

The apparatus used and methods followed at the European explosives-testing stations were carefully considered before the United States testing station was erected. Their experience particularly emphasized the importance of a suitable location for the United States testing station, one that would insure a uniform and constant supply of natural gas. Pittsburgh, Pa., was finally selected as a desirable location, and decision was reached to install there a large gallery and a cannon of practically the same size as that adopted by the Continental stations. In addition, a ballistic pendulum, similar to the one used at the English station, and the German type of apparatus for testing the physical and chemical characteristics of explosives were installed. It was decided that all explosives should be required to pass stemmed tests in the presence of highly inflammable gas mixtures, according to the English practice, and to pass supplemental tests made in the presence of coal dust alone; also, that all explosives should be required to pass such unstemmed tests as had been universally adopted by the Government testing stations on the Continent.

TESTS CONDUCTED.

After the gallery and other apparatus had been calibrated several types of so-called safety powders manufactured in the United States were tested in the gallery. Many of them passed when tests were

made according to the English practice, but none of them passed the test of being fired without stemming in the presence of a mixture of gas and air containing 8 per cent of gas. Further tests were made by firing unstemmed shots separately with three explosives, namely, black blasting powder, one of the so-called safety powders of the nitroglycerin class, and one of the ammonium nitrate class, in the presence of mixtures of gas and air in different percentages.

The results of tests indicated that the highest limit charge that could be established with unstemmed shots when fired in the presence of a mixture of gas and air containing 8 per cent of methane and ethane was only 100 grams.

During a visit to the foreign stations the writer witnessed a test made in the presence of an 8 per cent mixture of methane and air, with a "permitted" explosive somewhat similar in composition to the explosive of the nitroglycerin class mentioned above. No ignition occurred when 880 grams of the explosive was fired without stemming, but under the conditions of testing at the Pittsburgh station an ignition occurred when 150 grams was used.

Four different samples, each representing a different class of explosive, were procured through one of the foreign testing stations for comparative tests. They were said to represent the best types of explosives used abroad in coal mines, one of them having the same composition as an explosive that had passed the Continental tests with a limit charge of 880 grams plus. Like the domestic explosives previously tested, they passed the test of being fired with stemming, but the highest limit charge established with unstemmed shots in the presence of mixtures of air and 8 per cent of methane and ethane was only 50 grams. It was found after repeated tests that this limit charge could not be increased even when loaded under special charging densities.

The tabulation following includes the results of tests made at the Pittsburgh testing station on the four explosives mentioned above and seven other foreign explosives recently received. The method of conducting the tests was approximately the same as that employed at the foreign testing stations.

The results of the tests indicate that all of the foreign explosives, except explosive II, which detonated incompletely, would pass the Woolwich tests but that all would fail to pass the Belgian tests. Only three of the explosives would pass the test requirements requisite for their being placed on the United States permissible list.

It is to be noted that two of the explosives failed in tests 1 and 4. Two explosives failed in test 4 only. One explosive failed in test 1 and detonated incompletely in test 4. Two explosives failed in the friction test and in test 4, and one explosive failed to meet the requirements for poisonous gases.

LIMIT CHARGES WITH VARIOUS GAS PERCENTAGES.

No stemming was used in any of the tests, but tests were made with different loading densities in the bore of the cannon. It is to be noted that the limit charge with all of the foreign explosives tested in the presence of 8, $8\frac{1}{2}$, and 9 per cent gas mixtures was 0 gram in all tests, even though the explosive was loaded with different charging densities. (See figs. 1 to 4.)

When these explosives were fired in the presence of 10 per cent gas the highest limit charge established was 50 grams (explosive E). The conditions of loading in the cannon seemingly were not a factor in the limit charge established.

When the explosives were fired in the presence of 7 per cent gas the limit charge established was 0 gram for samples G and J. The limit charge established for sample I was 0 gram when the explosive was loaded with a density of 1, and 150 grams when loaded with air spacing. Sample E also gave a higher limit charge (100 grams) when loaded with air spacing than when loaded with a density of 1 (50 grams).

When the explosives were fired in the presence of 6 per cent gas the limit charge established with explosive G was 0 gram, and 1,000 grams with explosive I, the results being the same irrespective of the charging density. Explosive J gave a limit charge of 50 grams when air spacing was used, and of 0 gram when loaded with a charging density of 1. The limit charge established for sample E was 150 grams when loaded with air spacing, and also when loaded with a charging density of 1.

When the explosives were fired in the presence of 5 per cent gas, 50 grams was established as the limit charge for explosive G, and 1,000 grams for explosive J. Different charging densities did not change the results. Six hundred grams was established as the limit charge for explosive E when loaded with a density of 1, and 400 grams when loaded with air spacing.

The results of the tests indicated that the natural gas used at the Pittsburgh testing station is more sensitive than the pit gas used

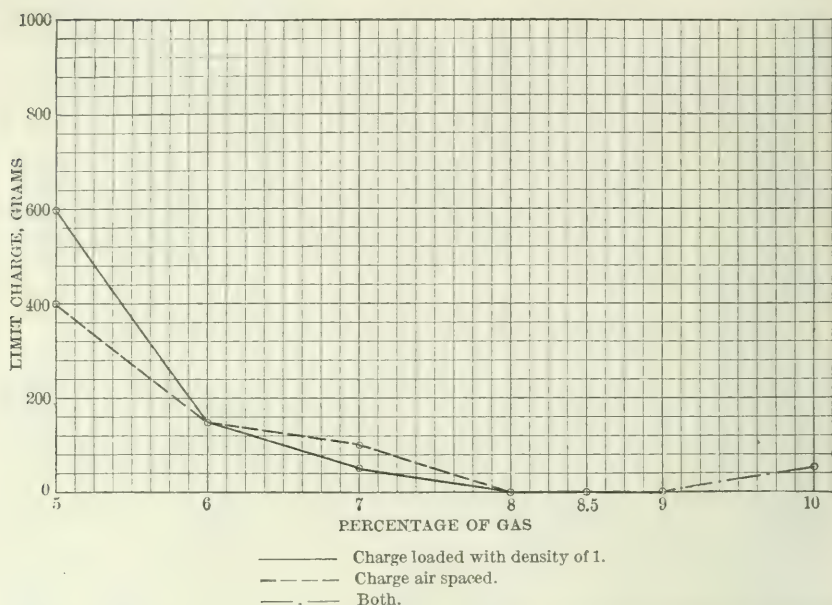


FIGURE 1.—Foreign explosive E. Limit charge established with various gas percentages. Composition of explosive: Moisture, 0.17; dinitrotoluene, 17.85; potassium chlorate, 75.36; castor oil, 5.32; mononitronaphthalene, 1.30; total 100.

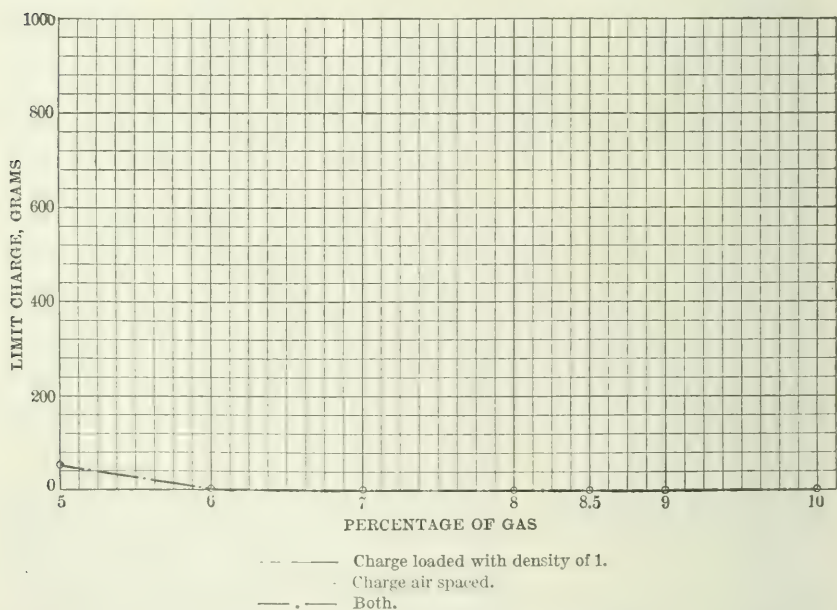


FIG. 2.—Foreign explosive G. Limit charge established with various gas percentages. Composition of explosive: Moisture, 0.52; nitroglycerin, 8.13; ammonium nitrate, 82.11; nitrotoluene, 3.57; wood pulp, 4.30; castor oil, 0.81; nitrocellulose, 0.56; total, 100.

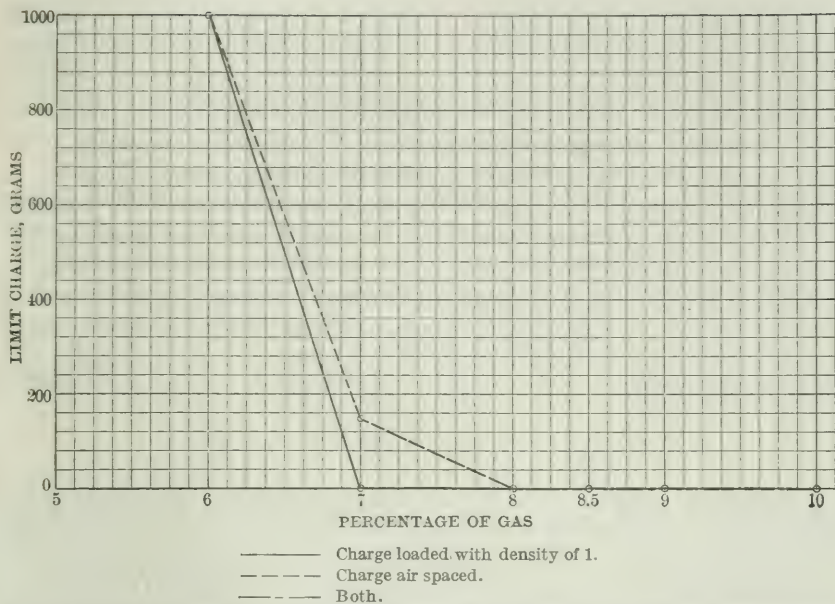


FIGURE 3.—Foreign explosive I. Limit charge established with various gas percentages. Composition of explosive: Moisture, 0.06; ammonium nitrate, 91.43; potassium nitrate, 3.50; rosin, 5.01; total, 100.

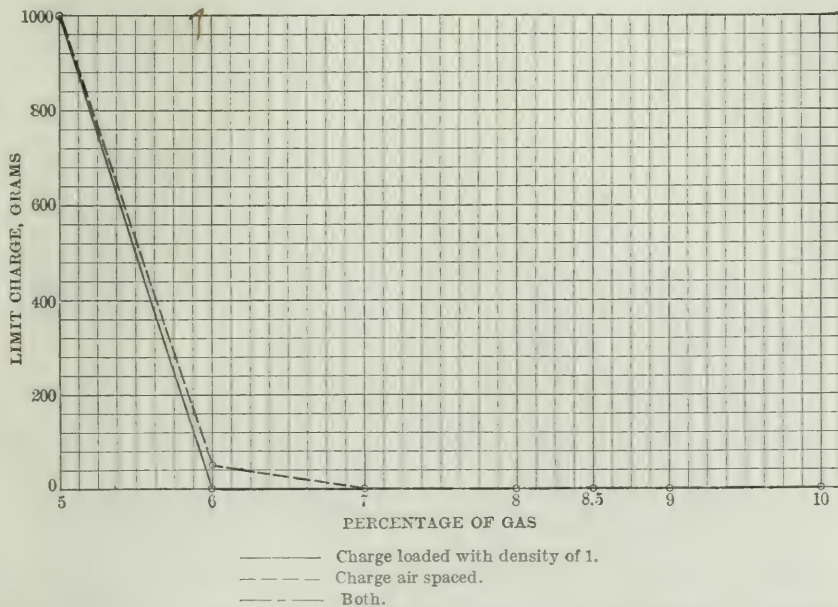


FIGURE 4.—Foreign explosive J. Limit charge established with various gas percentages. Composition of explosive: Moisture, 0.45; ammonium nitrate, 90.50; trinitrotoluene, 4.82; flour, 4.23; total, 100.

abroad and that it will be necessary to reduce the percentage of gas in order that the results of future tests may be comparable with results obtained in Europe. It was evident that the mixtures of gas and air that contained about 6 per cent of methane and ethane were equivalent to the 8 per cent mixtures abroad, and, further, that all explosives would be excluded if unstemmed shots were fired in the presence of air mixtures containing 8 per cent of methane and ethane. A conference of several of the leading coal operators was called at the Pittsburgh testing station, and the consensus of opinion was that a low percentage gas mixture with coal dust suspended in the air would more nearly represent the dangerous conditions that might exist in a coal mine, and that at least one of the tests should be made under these conditions with unstemmed shots and a charge of not less than 680 grams ($1\frac{1}{2}$ pounds).

STANDARDIZING APPARATUS AND METHODS.

The matter of a universal standard of methods and apparatus for testing coal-mining explosives is still an open one. Obviously, cooperation on the part of all stations aiming to unify or standardize apparatus and methods of testing explosives would be beneficial to all concerned, and it is hoped that such will eventually be the outcome.

It would seem that the design and the construction of all testing apparatus could be established on a uniform basis. In fact, the tendency at present to adopt the cylindrical type of steel gallery and steel cannons having a bore 55 mm. in diameter is universal. The unifying of methods of testing does not offer a ready solution.

In Belgium the mines are unusually gaseous and all explosives are required to pass a severe gas test. In recent years explosives have been tested in the presence of coal dust, but the dust used has had a relatively low percentage of volatile matter as compared with that used in the United States. It is contended that, as all the coals in Belgium with a high percentage of volatile matter have been practically exhausted, coal dust similar to that which exists in mines under actual working conditions should be used in the gallery.

In France great stress is put on the requirements as to the gaseous products of combustion of explosives. The nitroglycerin class of explosives is practically eliminated from use in French coal mines for the reason that they produce carbon monoxide on detonation. The writer's experience with permissible explosives of this class is that when they are properly used in coal mines of the United States in quantities less than $1\frac{1}{2}$ pounds per shot the amount of poisonous gases produced is so small that it is of little, if any, consequence, especially when the ventilation current is brought directly to the working face.

In England stemmed charges only are used for determining the permissibility of explosives for use in coal mines. This requirement would not always represent the conditions of mining in the United States. Miners have been known to fire permissible explosives in a drill hole with little, if any, stemming, although the practice is reprehensible. For this reason the Bureau of Mines requires an explosive to show satisfactory performance in an unstemmed shot before the explosive will be designated permissible. The bureau requires all explosives to meet practically all the European requirements in order to be placed on the permissible list; that is, satisfactory performance in shots in the presence of gas alone and of coal dust alone, and in unstemmed shots in mixtures of gas and coal dust.

PROPOSED REQUIREMENTS FOR PERMISSIBLE EXPLOSIVES IN COAL MINES.

SENSITIVENESS TO DETONATION.

It has been observed that many permissible explosives when stored lose sensitiveness to detonation and in some cases fail to detonate when fired by a proper detonator. This may be explained, perhaps, by the fact that the nitroglycerin contained in the explosive becomes more completely absorbed by the other ingredients; also by the absorption of water by the hygroscopic salts.

It was with this in view that one of the conditions specified by the Bureau of Mines for testing explosives was that the manufacturer be required to deliver to the experiment station three weeks prior to the date set for test 100 pounds of each explosive that he desired to have tested.

It is believed that several explosives have failed to pass the test requirements of the bureau that otherwise would have passed if they had not been 4 to 6 weeks old when tested. Supplemental tests have been made with all explosives on the permissible list, and it has been found that many of the ammonium-nitrate class of explosives after six months' storage at the Pittsburgh experiment station have either failed to detonate or detonated incompletely when retested. A few of the ammonium-nitrate explosives on being retested have shown signs of deterioration and have detonated incompletely after storage for four months. It is worthy of note that 2 of the 11 foreign explosives that were tested by the bureau failed to detonate completely when tested four months after they had been received.

It has been suggested that the bureau should consider the elimination from the permissible list of those explosives that become insensitive to detonation when stored under favorable conditions for a period of four months. I would like to hear from the visiting members of this conference as to whether any such requirement is in force abroad, and whether it is, in their opinion, advisable to have a requirement of this kind.

GASEOUS PRODUCTS.

The list of permissible explosives issued by the bureau January 1, 1911, contained a few explosives that on detonation in the Bichel gage developed large quantities of carbon monoxide. These explosives were later tested in coal mines. When the usual charge was fired in rooms, no appreciable amount of carbon monoxide was detected in samples of the mine air taken at the face immediately after the shot. However, when tests were made in narrow entries, ahead of the air, all mine-air samples taken immediately after charges of 680 grams had been fired showed the presence of carbon monoxide, one sample containing as much as 0.11 per cent. It was believed that these explosives, used under such conditions, would so vitiate the air near the face as to be harmful to the health of those directly connected with the work.

Other permissible explosives tested on detonation evolved less quantities of carbon monoxide in the gage tests. It was found, as a result of tests made in coal mines, that an explosive that on detonation in the gage evolved less than 158 liters of permanent poisonous gases from a charge of 680 grams would not, when used in coal mines, vitiate the mine air in narrow entries even when there was no circulation of air near the face. The highest percentage of carbon monoxide found in any of the mine-air samples taken immediately after the shot was 0.02 per cent.

When the later permissible list was issued (January 1, 1912) a few explosives were eliminated and a new requirement was adopted, namely, all explosives that, on detonation of a 680-gram charge, evolved 158 liters or more of permanent poisonous gases in gage tests shall not be considered permissible.

It is the opinion of the writer that the limitations that have been placed on the amount of poisonous gases evolved on detonation of explosives for use in coal mines is adequate, but I would like to hear an expression of opinion from the visiting members concerning this subject.

METAL-MINING EXPLOSIVES.

For driving tunnels and sinking shafts, and for metalliferous mining in this country, gelatin dynamites have been found well adapted and are used to a large extent. They produce on detonation smaller quantities of poisonous gases than any other class of explosives tested by the bureau. In work of this kind, the ventilation is usually defective; accordingly the gaseous product evolved on detonation of explosives is one of the most important considerations. The investigations that have been made by the bureau show that it is possible to manufacture gelatin dynamite having a slight oxygen

excess sufficient to insure the complete oxidation of all combustible materials, including paper wrappers.

Some of the manufacturers of explosives have taken advantage of the suggestions made by the bureau and are supplying the trade with the improved gelatin dynamites. In order to insure the use of better grades of explosives in metal mines, it will be necessary to publish, for the information of users of explosives, the nature and character of the many explosives offered for sale. Now that the bureau has been authorized by law to investigate the mining and the treatment of ores and other mineral substances, it will be possible to determine the permissibility of explosives for use in all mining and quarrying operations, and to publish a list of those explosives that pass the requirements satisfactorily.

The following is a tentative outline of the proposed requirements and I will appreciate any criticism or suggestion offered by this conference. The recommendation of specifications by this conference will be of material assistance to the director of the bureau in considering this subject.

The conditions under which explosives for use in metal mines and quarries will be tested in respect to priority of testing, method of deliveries, etc., will doubtless be the same as those under which explosives are tested for their permissibility in coal mines.

Proposed requirements of explosives for metal mines.

1. The explosives must be in a stable condition and all chemical and physical tests must not show any unfavorable results.

2. The explosives, on detonation, must not evolve carbon monoxide, hydrogen sulphide, nitrogen oxides, or other permanent poisonous gases, in quantities that may be considered harmful to the health of miners, when fired in 200-gram charges in the pressure gage.

3. Electric detonators will be used in the tests as recommended by the manufacturers, provided the grade recommended completely detonates or explodes the charge.

4. The explosives must pass pendulum friction tests in which the steel shoe is faced with wood fiber.

5. The propulsive and disruptive effect developed by each explosive will be determined and the results published, in order to serve as a useful guide in judging the efficiency of the explosive.

6. After an explosive shall have passed the above requirements it will be considered permissible for use only when used under the following conditions:

(a) That the explosive is in all respects similar to the sample submitted by the manufacturer for test.

(b) That detonators, or electric detonators, are used of not less efficiency than those prescribed, namely, those consisting by weight of 90 parts of mercury fulminate and 10 parts of potassium chlorate (or their equivalents).

(c) That the explosive, if frozen, shall be thoroughly thawed in a safe and suitable manner before use.

PROPOSED REQUIREMENTS OF EXPLOSIVES FOR QUARRIES.

Practically every class and grade of explosives are used in the United States in open work, such as quarries and railroad excavations. In work of this kind the efficiency of explosives is the most important consideration. The amount of poisonous gases produced on detonation of an explosive is of little importance, and the liability to cause ignition of gas or dust does not need consideration.

Tests will be made to determine the stability of each explosive and other tests that concern safety in the handling and use of such explosives. Information will also be published that will show the practical value of these explosives as well as offering the best means for selecting explosives suitable to meet the varying conditions of quarrying, etc.

PUBLICATIONS ON MINE ACCIDENTS AND METHODS OF MINING.

Limited editions of the following Bureau of Mines publications are available for free distribution. Copies may be obtained by applying to the Director, Bureau of Mines, Washington, D. C. Requests for all publications can not be granted.

BULLETIN 10. The use of permissible explosives, by J. J. Rutledge and Clarence Hall. 1912. 34 pp., 5 pls., 4 figs.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp., 10 pls., 12 figs. Reprint of United States Geological Survey Bulletin 423.

BULLETIN 20. The explosibility of coal dust, by G. S. Rice, with chapters by J. C. W. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. 204 pp., 14 pls., 28 figs. Reprint of United States Geological Survey Bulletin 425.

BULLETIN 42. The sampling and examination of mine gases and natural gas, by G. A. Burrell and F. M. Seibert. 1913. 116 pp., 2 pls., 23 figs.

BULLETIN 44. First national mine-safety demonstration, Pittsburgh, Pa., October 30 and 31, 1911, by H. M. Wilson and A. H. Fay, with a chapter on the explosion at the experimental mine, by G. S. Rice. 1912. 75 pp., 7 pls., 4 figs.

BULLETIN 45. Sand available for filling mine workings in the Northern Anthracite Coal Basin of Pennsylvania, by N. H. Darton. 1913. 33 pp., 8 pls., 5 figs.

BULLETIN 46. An investigation of explosion-proof mine motors, by H. H. Clark. 1912. 44 pp., 6 pls., 14 figs.

BULLETIN 48. The selection of explosives used in engineering and mining operations, by Clarence Hall and S. P. Howell. 1913. 50 pp., 3 pls., 7 figs.

BULLETIN 50. A laboratory study of the inflammability of coal dust, by J. C. W. Frazer, E. J. Hoffman, and L. A. Scholl, jr. 1913. 60 pp., 95 figs.

BULLETIN 52. Ignition of mine gases by the filaments of incandescent electric lamps, by H. H. Clark and L. C. Ilsley. 1913. 31 pp., 6 pls., 2 figs.

BULLETIN 53. Mining and treatment of kaolin and feldspar in the southern Appalachian region, by A. S. Watts. 1913. 170 pp. 16 pls., 12 figs.

BULLETIN 56. First series of coal-dust explosion tests in the experimental mine, by G. S. Rice, L. M. Jones, J. K. Clement, and W. L. Egy. 1913. 115 pp., 12 pls., 28 figs.

BULLETIN 60. Hydraulic mine filling; its use in the Pennsylvania anthracite fields; a preliminary report, by Charles Enzian. 1913. 77 pp., 3 pls., 12 figs.

BULLETIN 62. National mine-rescue and first-aid conference, Pittsburgh, Pa., September 23-26, 1912, by H. M. Wilson. 1913. 74 pp.

BULLETIN 66. Tests of permissible explosives, by Clarence Hall and S. P. Howell. 1913. 313 pp., 1 pl., 6 figs.

BULLETIN 68. Electric switches for use in gaseous mines, by H. H. Clark and R. W. Crocker. 1913. 40 pp., 6 pls.

BULLETIN 69. Coal-mine accidents in the United States and foreign countries, compiled by F. W. Horton. 1913. 102 pp., 3 pls., 40 figs.

TECHNICAL PAPER 4. The electrical section of the Bureau of Mines, its purpose and equipment, by H. H. Clark. 1911. 12 pp.

TECHNICAL PAPER 6. The rate of burning of fuse as influenced by temperature and pressure, by W. O. Snelling and W. C. Cope. 1912. 28 pp.

TECHNICAL PAPER 7. Investigations of fuse and miners' squibs, by Clarence Hall and S. P. Howell. 1912. 19 pp.

TECHNICAL PAPER 11. The use of mice and birds for detecting carbon monoxide after mine fires and explosions, by G. A. Burrell. 1912. 15 pp.

TECHNICAL PAPER 13. Gas analysis as an aid in fighting mine fires, by G. A. Burrell and F. M. Seibert. 1912. 16 pp., 1 fig.

TECHNICAL PAPER 14. Apparatus for gas-analysis laboratories at coal mines, by G. A. Burrell and F. M. Seibert. 1913. 24 pp., 7 figs.

TECHNICAL PAPER 15. An electrolytic method of preventing the corrosion of iron and steel, by J. K. Clement and L. V. Walker. 1913. 19 pp., 10 figs.

TECHNICAL PAPER 17. The effect of stemming on the efficiency of explosives, by W. O. Snelling and Clarence Hall. 1912. 20 pp., 11 figs.

TECHNICAL PAPER 18. Magazines and thaw houses for explosives, by Clarence Hall and S. P. Howell. 1912. 34 pp., 1 pl., 5 figs.

TECHNICAL PAPER 19. The factor of safety in mine electrical installations, by H. H. Clark. 1912. 14 pp.

TECHNICAL PAPER 21. The prevention of mine explosions; report and recommendations, by Victor Watteyne, Carl Meissner, and Arthur Desborough. 12 pp. Reprint of United States Geological Survey Bulletin 369.

TECHNICAL PAPER 22. Electrical symbols for mine maps, by H. H. Clark. 1912. 11 pp., 8 figs.

TECHNICAL PAPER 23. Ignition of mine gas by miniature electric lamps with tungsten filaments, by H. H. Clark. 1912. 5 pp.

TECHNICAL PAPER 24. Mine fires, a preliminary study, by G. S. Rice. 1912. 51 pp., 1 fig.

TECHNICAL PAPER 28. The ignition of mine gas by standard incandescent lamps, by H. H. Clark. 1912. 6 pp.

TECHNICAL PAPER 29. Training with mine-rescue breathing apparatus, by J. W. Paul. 1912. 16 pp.

TECHNICAL PAPER 30. Mine-accident prevention at Lake Superior iron mines, by D. E. Woodbridge. 1913. 38 pp., 9 figs.

TECHNICAL PAPER 32. The cementing process of excluding water from oil wells, as practiced in California, by Ralph Arnold and V. R. Garfias. 1913. 12 pp., 1 fig.

TECHNICAL PAPER 39. The inflammable gases in mine air, by G. A. Burrell and F. M. Seibert. 1913. 24 pp., 2 figs.

TECHNICAL PAPER 40. Metal-mine accidents in the United States during the calendar year 1911, compiled by A. H. Fay. 1913. 54 pp.

TECHNICAL PAPER 41. The mining and treatment of lead and zinc ores in the Joplin district, Mo.; a preliminary report, by C. A. Wright. 1913. 43 pp., 5 figs.

TECHNICAL PAPER 42. The prevention of waste of oil and gas from flowing wells in California, with a discussion of special methods used by J. A. Pollard, by Ralph Arnold and V. R. Garfias. 1913. 15 pp., 2 pls., 4 figs.

TECHNICAL PAPER 43. The influence of inert gases on inflammable gaseous mixtures, by J. K. Clement. 1913. 24 pp., 1 pl., 8 figs.

TECHNICAL PAPER 44. Safety electric switches for mines, by H. H. Clark. 1913. 8 pp.

TECHNICAL PAPER 46. Quarry accidents in the United States during the calendar year 1911, compiled by A. H. Fay. 1913. 32 pp.

TECHNICAL PAPER 47. Portable electric mine lamps, by H. H. Clark. 1913. 13 pp.

TECHNICAL PAPER 48. Coal-mine accidents in the United States, 1896-1912, with monthly statistics for 1912, compiled by F. W. Horton. 1913. 74 pp., 10 figs.

TECHNICAL PAPER 52. Permissible explosives tested prior to March 1, 1913, by Clarence Hall. 1913. 11 pp.

TECHNICAL PAPER 55. The production and use of brown coal in the vicinity of Cologne, Germany, by C. A. Davis. 1913. 15 pp.

TECHNICAL PAPER 58. Action of acid mine water on the insulation of electric conductors; a preliminary report, by H. H. Clark and L. C. Ilsley. 1913. 26 pp., 1 fig.

TECHNICAL PAPER 59. Fires in Lake Superior iron mines, by Edwin Higgins. 1913. 34 pp., 2 pls.

TECHNICAL PAPER 61. Metal-mine accidents in the United States during the calendar year 1912, compiled by A. H. Fay. 1913. 76 pp., 1 fig.

MINERS' CIRCULAR 4. The use and care of mine-rescue breathing apparatus, by J. W. Paul. 1911. 24 pp., 5 figs.

MINERS' CIRCULAR 5. Electrical accidents in mines, their causes and prevention, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.

MINERS' CIRCULAR 6. Permissible explosives tested prior to January 1, 1912, and precautions to be taken in their use, by Clarence Hall. 1912. 20 pp.

MINERS' CIRCULAR 8. First-aid instructions for miners, by M. W. Glasgow, W. A. Raudenbush, and C. O. Roberts. 1913. 67 pp., 51 figs.

MINERS' CIRCULAR 9. Accidents from falls of roof and coal, by G. S. Rice. 1912. 16 pp.

MINERS' CIRCULAR 10. Mine fires and how to fight them, by J. W. Paul. 1912. 14 pp.

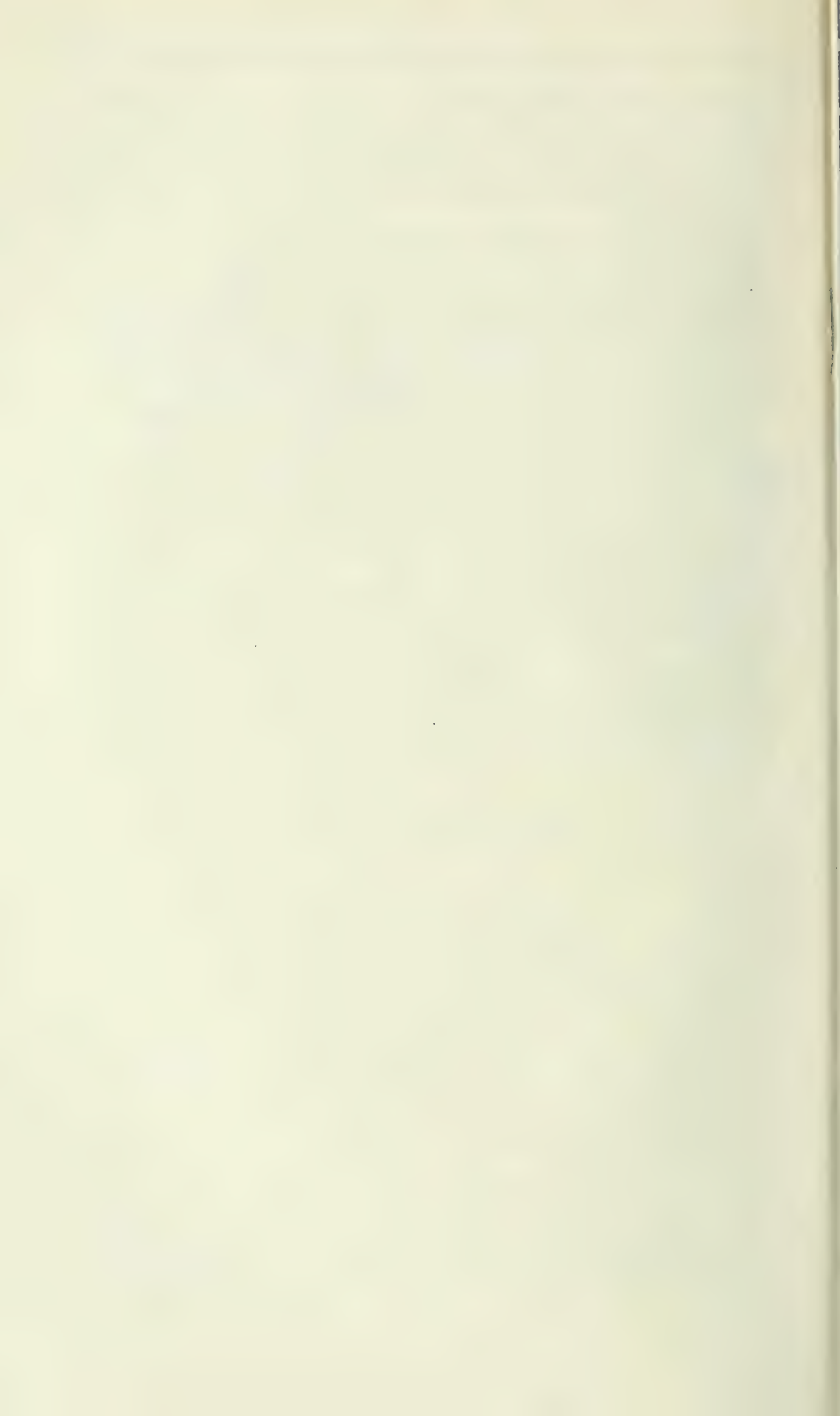
MINERS' CIRCULAR 11. Accidents from mine cars and locomotives, by L. M. Jones. 1912. 16 pp.

MINERS' CIRCULAR 12. The use and care of miners' safety lamps, by J. W. Paul. 1913. 16 pp., 4 figs.

MINERS' CIRCULAR 13. Safety in tunneling, by D. W. Brunton and J. A. Davis. 1913. 19 pp.

MINERS' CIRCULAR 14. Gases found in coal mines, by G. A. Burrell and F. M. Seibert. 1914. 23 pp.

MINERS' CIRCULAR 15. Rules for mine-rescue and first-aid field contests, by J. W. Paul. 1913. 12 pp.



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